INSTRUCTIONS

FOR

ENGINEMEN

GOVERNING

THE CARE, MAINTENANCE AND ECONOMICAL OPERATION OF THE LOCOMOTIVE

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PREFACE

The instructions contained herein are for the information and guidance of employes of the Atchison, Topeka and Santa Fe Railway Company, whose duties require that they be familiar with the care and operation of the locomotive.

It is the desire of this company to employ firemen who will in time become competent locomotive enginemen, and who by proper study and application to duty may prepare themselves for appointment to higher positions of responsibility. This requires that an employe should have at least a common school education, good habits and be in good physical condition. He should be alert, with good reasoning faculties, and a man of sound judgment. Having these qualifications advancement will come to those who are conscientious in discharging their duties and who devote some of their leisure hours to study.

When entering the service as a locomotive fireman an employe should understand that he is entering his apprenticeship as an engineer, and should, during his period of firing service, avail himself of every opportunity to learn everything possible connected with his duties and with the duties he will be called upon to perform after being promoted. This book is issued for the purpose of assisting such firemen and for the information of enginemen already in the service. All such employes are invited, in fact, urged to go to the Master Mechanic, General Foreman, Road Foreman and Air Brake Instructors, or any other official, and ask them for such information as may be required on any points in connection with their work.

It is good practice to observe how other men care for breakdowns or conditions which effect the proper operation or maintenance of the locomotive, thereby benefiting through the experience of others. However, failure to practice what you learn will result in its soon being partially or wholly forgotten. Remember that it is your duty to ascertain, as far as tests and examinations will permit, the general condition of locomotives under your charge, and either to apply the proper remedy or make a clear report of any troubles on the usual work reports.

Much valuable information may be obtained by noting the construction of the various parts of the locomotive while it is undergoing repairs. For this purpose periodical visits to the shop and roundhouse will provide a fund of information difficult to obtain otherwise, as the interior parts are dismantled and may be examined at leisure.

Study carefully the diagram showing the complete locomotive, in order to become familiar with:

The boiler, which is a power generating plant.

The engines for utilizing the power generated.

The frames to provide a foundation for carrying the boiler and engines.

A series of wheels secured in the frames and which are turned by the engines.

INDEX.

FIG. 1.

Names of Parts Shown in Fig. 1

1. Cab
2. Cab ventilator lever
3. Cab ventilator
4. Whistle lever
5. Whistle rope
6. Steam whistle
7. Water glass
8. Gauge cock
9. Main throttle
10. Throttle quadrant
11. Main throttle stem
12. Main throttle bell crank
13. Main throttle valve
14. Throttle stand pipe
15. Throttle dry pipe
16. Reverse lever
17. Reverse lever quadrant
18. Reverse lever reach rod
19. Power reverse gear
20. Power reverse gear reach rod
21. Reverse shaft arm
22. Reverse shaft
23. Blow off cock lever
24. Blow off cock
25. Adjustable seat box
26. Adjustable seat cushion
27. Adjustable seat back rest
28. Brakeman's seat
29. Stoker elevator
30. Stoker distributor elbow
31. Automatic stoker engine
32. Fire door ring or opening
33. Fire box
34. Fire box door sheet
35. Crown sheet
36. Back flue sheet
37. Back head
38. Throat sheet
39. Wrapper sheet
40. Staybolt
41. Boiler stayrods
42. Crown sheet radial stays
43. Expansion stays
44. Arch flue plug
45. Arch tube
46. Brick arch
47. Mud ring
48. Grate frame
49. Grate frame support or bracket

50. Rocking grate
51. Dump grate post
52. Grate shaker post
53. Power grate shaker cylinder
54. Power grate shaker reach rod
55. Grate shaker post reach rod
56. Grate connecting rod
57. Grate shaker arm
58. Ash pan
59. Front ash pan slide post
60. Center ash pan slide post
61. Back ash pan slide post
62. Front ash pan hopper
63. Center ash pan hopper
64. Back ash pan hopper
65. Ash pan slide
66. Cylinder cock operating lever
67. Cylinder cock reach rod
68. Cylinder cock lever
69. Cylinder cock slide rod
70. Cylinder cocks
71. Cylinder cock drip pan
72. Hand rail or grab iron
73. Injector throttle
74. Injector steam pipe
75. Injector
76. Injector feed pipe
77. Injector overflow muffler
78. Injector branch pipe
79. Injector line check
80. Boiler check
81. Electric headlight turbine and generator
82. Superheater flue (superheater boiler flue)
83. Boiler flue
84. Superheater tubes or units
85. Superheater header
86. Front flue sheet
87. Superheater damper operating cylinder
88. Superheater damper operating cylinder counter-weight
89. Superheater damper cylinder steam pipe
90. Superheater damper
91. Trailer spring equalizer
92. Trailer spring back hanger
93. Trailer spring front hanger
94. Trailer spring
95. Trailer equalizer
96. Trailer truck frame
97. Trailer truck box
98. Trailer truck wheel
99. Trailer truck equalizer post
100. Trailer radius bar
101. Driving box brass

102. Driving box
103. Driving box cellar
104. Driving box wedge
105. Driving box shoe
106. Driving box adjusting spring and rod
107. Driving box cellar bolt
108. Driving spring saddle
109. Driving spring equalizer
110. Driving spring hanger
111. Main driving spring
112. Back driving spring cross equalizer hanger
113. Main frame back section
114. Main frame
115. Main frame front section
116. Pedestal brace or binder
117. Back driving brake hanger
118. No. 3 Driving brake hanger lever
119. No. 2 Driving brake hanger lever
120. Front driving brake hanger lever
121. Driving brake head
122. Driving brake shoe
123. Driving brake adjusting screw
124. Driving axle
125. Driving axle key
126. Driving wheel
127. Driving wheel tire
128. Driving wheel counterbalance
129. Back section or No. 3 side rod
130. Intermediate or No. 2 side rod
131. Front or No. 1 side rod
132. Side rod knuckle joint
133. Main rod
134. Main rod strap
135. Main rod grease cup
136. Back crank pin
137. Intermediate or No. 2 crank pin
138. Front crank pin
139. Main crank pin
140. Running board
141. Running board bracket
142. Front running board
143. Back sand pipe
144. Front sand pipe
145. Pneumatic sand traps
146. Sand box or dome
147. Sand box cover
148. Main reservoir
149. Main reservoir flexible pipe union
150. Main reservoir radiating or equalizing pipe
151. Safety valves
152. Blow off valves
153. Steam dome

154. Hand rail
155. Boiler lagging
156. Boiler jacket
157. Boiler waist sheet
158. Engine number indicator
159. Bell
160. Pneumatic bell ringer
161. Smoke stack
162. Petticoat pipe
163. Adjustable diaphragm plate
164. Front end netting
165. Drafting table plate
166. Draft plate
167. Draft plate
168. Manhole for cleaning and inspecting inside smoke box
169. Cinder hopper
170. Front end or smoke box
171. Front end door ring
172. Front end door
173. Front end number plate
174. Headlight
175. Smoke arch or pilot brace
176. Pilot beam
177. Pilot heel brace
178. Pilot step
179. Pilot
180. Pilot automatic coupler
181. Automatic coupler lock lifter
182. Automatic coupler uncoupling lever
183. Automatic coupler lock lifter chain
184. Engine truck center casting
185. Engine truck spring hanger
186. Engine truck spring
187. Engine truck long equalizer
188. Engine truck long equalizer post or fulcrum under cylinder saddles
189. Engine truck radius bar
190. Engine truck axle
191. Engine truck wheel
192. Cylinder saddle
193. Cylinder
194. Front cylinder head
195. Back cylinder head
196. Main valve chamber
197. Main valve bushing
198. Main valve packing rings
199. Main or piston valve
200. Front main valve chamber head
201. Main or piston valve stem
202. Valve stem cross head guide
203. Valve stem cross head
204. Steam pipe connecting superheater header to outside steam pipe connection

205. Outside steam pipe connection
206. Exhaust nozzle stand
207. Exhaust nozzle tip
208. Front steam port to cylinder
209. Back steam port to cylinder
210. Steam piston head
211. Steam piston head bull ring
212. Steam piston cylinder packing rings
213. Piston rod
214. Cross head or piston rod key
215. Cross head wrist pin
216. Cross head
217. Valve gear union link
218. Combination lever
219. Radius bar
220. Radius bar hanger
221. Valve gear frame or link bearer
222. Reversing link
223. Valve gear eccentric rod
224. Valve gear eccentric crank
225. Bottom guide bar
226. Top guide bar
227. Guide step
228. Guide yoke or bearer
229. Counterbalance spring
230. Inspection and oiling ladder
231. Exhaust nozzle split or bridge
232. Tate flexible staybolt
233. Tate flexible flush-sleeve staybolt
234. Fountain
235. Fountain dry pipe
236. Blower pipe

Diagram of Complete Locomotive (Fig. 1) Following this page.

THE LOCOMOTIVE BOILER

Construction and Name of Parts

Fig. 2 shows the construction and name of parts of a modern radial stay extended wagon top type of locomotive boiler, which consists of an oblong box with a circular top made of steel plating, connected to a cylindrical part which is commonly known as the barrel of the boiler. That part of the boiler enclosing the firebox is known as the outer casing or shell. The firebox corresponds in shape to the back end and sides of the outer casing or shell, a space being provided between the firebox sheets and those of the outer casing which provides for the firebox being surrounded by water. The front, or cylindrical part of the boiler encloses the flues which are secured at the front to the front flue sheet and at the back to the inner or firebox flue sheet.

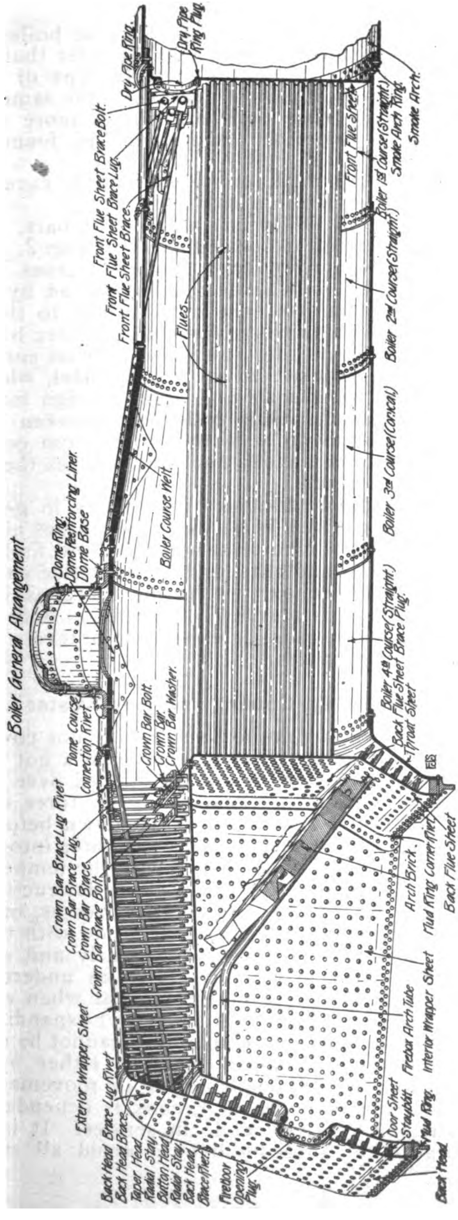
This arrangement provides that all parts of the firebox, as well as the flues, are completely surrounded by water, and it also provides that when fuel is burned in the firebox, the heat will be transmitted by the flues and firebox plates to the water; the unused gases and smoke having free passage from the firebox through the flues to the smoke box and smoke stack.

The smoke box is formed by extending the cylindrical part of the boiler beyond the front flue sheet. The boiler shell is provided with a steam dome on top of the shell which forms a chamber where steam may collect and free itself from the water in the boiler before passing through the throttle valve to the cylinders.

The flues in a locomotive boiler are known as fire tubes, because the heat passes through them, while the arch tubes, of which there are usually four in each firebox, are called water tubes because the fire is on the outside and the water passes through them.

The firebox sheets and flues constitute what is known as the heating surface. In addition to this heating surface there is additional, or superheater heating surface in many boilers, which superheats the steam after it leaves the boiler and while it is passing from the boiler to the cylinders. Comparing the flue heating area with that of the area of the firebox plates shows that the plate heating surface equals only five per cent of the flue heating surface, but the five per cent of firebox heating surface generates about forty per cent of the steam. This fact should be remembered.

In the locomotive boiler a large number of small flues are provided instead of a few large flues, in order that the heat and gases passing from the firebox to the smoke box will be split up and come into contact with a larger flue surface. If large flues were used great quantities of heat would pass through the center of the flues without coming into contact with the surface of the flue, such heat would pass away and be lost. A large number of small tubes also provides for the heat being more evenly distributed through the boiler shell water space. The small flue is also safer and there is less liability of dangerous accidents due to flue failures. The small flue can be made of thinner material, which permits the heat to be more easily transmitted to the water which surround the flues.



Boiler General Arrangement
Dome Ring
Dome Reinforcing Liner
Dome Base
Dome Course
Connection Rivet
Boiler Course Welt
Crown Bar Bolt
Crown Bar
Crown Bar Washer
Front Flue Sheet Brace Bolt
Front Flue Sheet Brace Lug
Front Flue Sheet Brace
Dry Pipe Ring
Dry Pipe Ring Plug
Flues
Front Flue Sheet
Boiler 1st Course (Straight)
Smoke Arch Ring
Smoke Arch
Boiler 2nd Course (Straight)
Boiler 3rd Course (Conical)
Boiler 4th Course (Straight)
Back Flue Sheet Brace Plug
Throat Sheet
Arch Brick
Mud Ring Corner Rivet
Back Flue Sheet
Crown Bar Brace Lug Rivet
Crown Bar Brace Lug
Crown Bar Brace
Crown Bar Brace Bolt
Exterior Wrapper Sheet
Firebox Arch Tube
Interior Wrapper Sheet
Door Sheet
Staybolt
Mud Ring
Back Head
Back Head Brace Lug Rivet
Back Head Brace
Taper Head
Radial Stay
Button Head Radial Stay
Back Head Brace Rivet
Firebox Opening Plug

FIG. 2.

In the extended wagon top type of locomotive boiler the back part or outer shell is considerably larger in diameter than the front section or cylindrical part; while the straight type of boiler has the outer shell and cylindrical part of practically the same diameter. The extended wagon top type therefore allows more steam and water space and gives superior performance in foaming water territory.

Locomotive boilers are made entirely of steel, except firebox rivets, staybolts and stays, which are of iron.

The crown bar type of boiler has a series of bars, such as is shown at the forward end of the crown sheet in Fig. 2. It will be noted that there are two crown bars reaching across the crown sheet, the balance of the crown sheet is supported by what are called radial stays reaching from the crown sheet to the exterior wrapper sheet. The crown bar type firebox or boiler has a series of crown bars which supports the crown sheet for its entire length. These crown bars set very close to the crown sheet, which makes it difficult to scrape or wash scale and other foreign matter from the top of the crown sheet. Scale collecting between the crown sheet and crown bars tends to keep the water from coming into direct contact with the crown sheet, and thus reduces the efficiency of the boiler to generate steam.

There are three common designs of fireboxes in general use. The narrow deep firebox, which is between the frames and extends below the top frame rails. The semi-wide shallow firebox which rests on top of the frames and extends to the outside edges of the frame rails, and the wide firebox type having a firebox wider than the frames and extending outside the frame rails on both sides, and resting on top of the frame rails, or expansion brackets which are secured to the top of the frames.

Effect of Heating, Cooling and Low Water

When the crown sheet or firebox sheets are not covered with water, they become overheated very quickly with a hot fire in the firebox. If for any reason water is not maintained over the crown sheet, and the sheets become overheated, do not force cold water into the boiler. The boiler should be cooled down before any attempt is made to refill it, because forcing cold water into the boiler when it is very hot produces sudden changes in the temperatures of the various parts of the sheets, and sets up very destructive strains.

The prevention of destructive strains and stresses, or reducing their amplitude should interest all who have to do with the upkeep of the locomotive. In order to bring out clearly and simply the cause of destructive stresses it should fully be understood that the contraction or expansion in a body of metal when changes of temperature occur is irresistable. A firebox sheet expanding or contracting as a result of a change in temperature cannot be restrained. It is certain to find relief in some direction, either by self destruction or destroying the obstacle opposing its movement.

The life of a locomotive boiler or firebox is dependant largely upon the care which it receives while in service. It is not possible in the operation of a locomotive to avoid all strains and

stresses, but it is possible, practical and beneficial to reduce the frequency of the stresses and also their amplitude. In other words, if by any means the severity of strains is reduced even though their frequency be increased, the period between failures will be prolonged, the time between repairs and the life of fireboxes and boilers will be lengthened.

Fig. 3, which is a diagram of the boiler shown in Fig. 1, illustrates the action of metal when heating and cooling takes place. It will be noted that the boiler is divided into sections. After steam is generated in the boiler to 200 lbs. it is found that the boiler has expanded nearly one inch, which demonstrates that metal expands as heating takes place and that when the boiler cools the metal contracts. Expansion and contraction of the metals thus sets up strains and stresses at various parts in the boiler, and it is important that as these strains are developed that they be developed slowly, in order that the effect of heating or cooling will be distributed throughout the boiler so that the expansion or contraction will be as uniform as possible throughout all its parts.

TEMPERATURES OF STEAM AND WATER

Working injectors while engines are standing causes more frequent and greater inequality of temperatures throughout the boiler and the development of more destructive stresses than any other cause. To illustrate: Temperature of the steam in a boiler such as is shown in Fig. 1, at 190 pounds pressure is 383 degrees Fahrenheit. This is also the temperature of the water at that steam pressure. When an injector is operated the water passing through the injector on its way to the boiler is heated to a temperature of from 160 to 200 degrees. It is therefore from 183 to 223 degrees cooler than the water within the boiler. The water from the injector being cooler is heavier than the higher temperature water in the boiler, and on entering the boiler must take a downward course and continue downward until it reaches the lowest part. The weight of a cubic foot of water as it enters the boiler from the injector is 60⅛ pounds, while a cubic foot of water at 190 pounds steam pressure, or 383 degrees is only 54¼ pounds. A cubic foot of water at 383 degrees is 5⅞ pounds, or 9 per cent lighter than the water at 200 degrees delivered into the boiler from the injector. This difference of weight makes it clear why the cooler and heavier water seeks the lower levels and displaces the hotter lighter water.

CAPACITY OF WATER SPACES AND EFFECT OF OPERATING INJECTOR WITH ENGINE STANDING

That part of the boiler immediately above the mud ring and extending upward toward the crown sheet, is known as the water leg of a boiler. Referring to Fig. 3-A (which is a reproduction of the firebox end of the boiler shown in Fig. 1) it will be noted that when the water is raised 28 inches above the mud ring that the water leg and the bottom of the boiler is filled up to the third row of flues. This space when filled with water contains 396 gallons. Any inch of the boiler water space that the lower half of the water glass shows will average 84 gallons, therefore, when the injector delivers enough water to the boiler to show an increase of one inch in the glass, from 19 to 20 inches of cooler water flows to the lower firebox water spaces, and reduces the temperature of the parts of the firebox sheets it is in contact with. These figures show that if water is injected into the boiler until the glass shows a gain of five inches, the height of the cooler water in the lower parts is from 28 to 29 inches, which not only covers 28 inches of firebox sheets, but three rows of the lower flues are submerged in water from 100 to 200 degrees cooler than the water above. If the flues are twenty feet long, the cooler ones are from 1/8 to 1/4 of an inch shorter than the upper ones, and the side sheets are from 1-16 to 1/8 inch shorter at the cooler portions than at the hotter parts above; and these variations in length between parts of the same sheet and between the upper and lower flues establish the stresses that develop leaks and the necessity for repairs. The cooler water assumes a horizontal strata under the hotter water, as shown below the 28 inch line in Fig. 3-A. The parts affected must conform in length to the temperature of the waters they are in contact with. Unequal temperatures between parts of the same structure are the cause of boiler and firebox deterioration. Improper handling of the injector is responsible for more boiler leaks than all other causes combined. A large per cent of these troubles could be avoided by improved handling.

SUPERHEATER LOCOMOTIVES

Fig. 4 shows the steam superheater in place, and also the location of dampers, and the method of securing the superheater pipes or units to the header. The arrow points indicate the travel of the steam from the throttle valve through the dry pipe, thence through the superheater and steam pipe to the valve chambers and cylinders.

The fire tube or high degree type of superheater is a superheater having tubes which connect at one end to a passage communicating directly with the steam admission or dry pipe leading from the throttle valve. These pipes then extend into large boiler flues, the ends of the superheater pipes reaching back through these flues close to the back flue sheet, where the pipe bends and returns through the flue to the smoke box, another return bend being placed at this point, the pipe again entering the same flue and reaching almost to the first return bend, where another return bend is placed and the pipe extended out into the smoke box and connected to the same casting which contains the live steam passage; however the latter end of this pipe connects to a passage leading to the steam pipes and steam chests. The casting to which these tubes are connected is called the superheater header. One side of the header connects directly to the dry pipe and the other side connects to the steam pipes leading to the steam chests or valve chambers.

A number of large flues are placed in the top part of the boiler, into each of these is inserted one of the above described coils of pipe. Each one of these coils is designated as a unit, the superheater is therefore made up of a number of units, all conected to one header. Steam, after leaving the throttle valve, passes to the superheater header, then through the superheater tubes or units, back into the header and thence to the steam chests.

The front end of the superheater units, and also the superheater headers are separated from the rest of the smoke box by means of a vertical partition plate, located just in front of the superheater body and extending across the smoke box and from the top of the smoke box down to the back edges of the table plate. From the bottom edge of this partition plate a horizontal plate reaches across the smoke box, back to the front flue sheet, just below the large flues. This horizontal plate contains an opening into which is fitted a damper. This damper is for the purpose of protecting the superheater pipes or units against overheating when there is no steam flowing through them, especially when the blower is on. It accomplishes this by shutting off the flow of hot gases through the large flues. When the damper is closed, the hot gases are not drawn through the large flues, therefore, if the engine should be working steam at this time the temperature of the steam passing through the superheater tubes would not be increased and the value of the superheater would be lost. The steaming qualities of the engine would also be reduced on account of the large flue area which would be obstructed.

If the damper remains open when the engine is not working steam the superheater tubes at the firebox end would be overheated and burn, on account of there being no steam flowing

through them and their being subjected to the intense heat at that time.

In order to provide for automatically opening and closing the superheater damper at the proper time a small cylinder is provided. This cylinder has a steam pipe connection leading to the steam chest, so that when the throttle is open and pressure builds up in the steam chest it acts upon the piston in this cylinder. This piston is connected to a system of levers, a movement of the piston due to the steam pressure causes the damper to be opened. However, when the throttle is closed and the steam pressure is exhausted from the steam chest, the piston returns to its normal position, due to a large counter-weight being fastened to one of the operating levers. When this counter-weight is raised the damper is opened, and its weight is sufficient to return the piston to its normal position, thus causing the damper to close as soon as the throttle is closed.

The engineer can, by observing the position of the counter-weight, know whether the operating mechanism is performing properly to open and close the damper when it should. In some cases, where the counter-weight is so located that it cannot be conveniently seen from the cab, a small indicator is attached to the counter-weight or lever. This indicator, which is so arranged that it can be conveniently observed at all times, affords the engineer a means of knowing whether the damper is working properly.

Should the operating mechanism become disconnected, the damper may remain closed, although the counter-weight raises when the throttle is open. If this occurs the steaming qualities of the engine will be interfered with, and the efficiency of the superheater will be reduced, thus calling attention to the fact that some defect exists, in which case the engineer should investigate to determine whether or not the damper is opening and closing with a movement of the counter-weight. A small hand-hole plate is placed at the side of the smoke arch which may be removed, raising and lowing the counter-weight by hand and observing the action of the damper at this time will determine whether or not these parts are operating properly.

Superheating steam increases its elasticity. However, adding heat to steam does not increase its power to start a load. Two hundred pounds pressure per square inch exerts the same starting force, whether of superheated or saturated steam. A certain pressure of saturated steam represents a certain steam temperature and when saturated steam from a boiler enters a cylinder at 368 degrees, it represents a pressure or force of 170 pounds per square inch, and as it loses its heat it loses its power. Thus when it has lost 100 degrees of heat, that is, when its temperature has been reduced from 368 degrees to 268 degrees, the steam pressure has also been reduced, falling from 170 pounds per square inch to 40 pounds.

Superheating adds to the steam after it leaves the boiler and before it enters the cylinder, from 100 to 300 degrees of heat. This extra or additional heat is sufficient to overcome the cooling effects of the steam chest and cylinders to the extent that a higher average

pressure is maintained in the cylinders the whole length of the stroke. The maintaining of the steam at a higher temperature in the cylinder is the reason why superheated steam holds its power of doing work longer, and why it does more work than an equal weight of saturated steam.

Ability to obtain or failure to obtain the best results from a superheater rests largely in the hands of the engineman. A simple rule for obtaining the best results may be expressed in seven words: "Keep the water out of the superheater." The moment the water gets into it, the efficiency of the locomotive drops. Water may not show at the stack or cylinders, the superheater may be turning it into steam, which however is not superheated to the same degree as would be the case if no water were present, and moreover the solids left behind by the water tend to scale up the inside of the superheater tubes, reducing their efficiency. The solid matter also mingles with the lubricants in the cylinders, reducing the lubricating qualities of the cylinder oil.

There is approximately 75 linear feet of pipe in each superheater unit, the extreme back end of the unit is about two feet from the firebox end of the flues. The damper in the front end should never under any conditions be opened except when the locomotive is using steam in the cylinders. If the damper remains open with no steam flowing through the superheater tubes, and there is a good fire in the box, with a strong draft through the flues, the units have been known to get red hot for about six or eight feet, reaching a temperature of 900 to 1,200 degrees. Suppose then, while these pipes are at that high temperature, the throttle is opened and steam at 383 degrees is admitted through these hot pipes. Think of the tremendously quick reduction of temperature which takes place, and what happens when an almost instantaneous change of 500 or 800 degrees is made in a pipe 75 feet long. When one contemplates the possibility of damage under those conditions it seems marvelous, not that trouble is experienced with leaky unit joints and bends, and broken headers; but that more trouble is not experienced.

Fig. 5 shows the fire tube superheater as applied to a locomotive; it consists essentially of the superheater header and a series of superheater units, generally arranged in several horizontal rows across the top part of the boiler.

The superheater header replaces the ordinary tee or "nigger head." It is provided, like the tee, with connections for the dry pipe and steam pipes, but has in addition, internal walls, which prevent the direct flow of steam from the dry pipe to the steam pipes. The connecting passage between the dry pipe and the steam pipes is provided by the superheater units. This compels all of the steam to pass through the superheater units on the way to the cylinders.

Each unit consists of a continuous pipe, formed of four seamless steel tubes, connected by three return bends. The front ends of the units are bent and clamped to conical seats in the face of the superheater header in the smoke box, as shown in Fig. 5. The connections are made steam-tight by ball joints, the balls being formed on the ends of the pipe. The units are placed in the

superheater flues which are 5⅜ inches or 5½ inches outside diameter (depending upon whether used with the 2 inch or 2¼ inch boiler tube). They extend full size from the front flue sheet to within about 8 inches of the firebox. Beyond this point the flue is reduced to 4½ inches outside diameter by swaging.

In operation, part of the hot firebox gases flow through the large flues. A proportion of their heat is absorbed by the pipes of the superheater units and transferred to the steam passing through them on its way from the dry pipe to the cylinders. As a result the steam has a higher temperature on reaching the cylinders than when it left the boiler; briefly stated, it is superheated steam.

Hand Holes

Hand holes 8 inches in diameter are provided in each side of the smoke box, slightly below the center of the face of the header and directly opposite each other. These hand holes afford a means of inspection to determine whether the unit joints are leaking, without removing the damper or baffle plates.

Operation

The general operation of the superheater locomotive is the same as that of the saturated steam locomotive.

CYLINDER COCKS SHOULD BE LEFT OPEN TO DRAIN THE CYLINDERS ETC., WHILE STANDING. IN STARTING THE CYLINDER COCKS SHOULD REMAIN OPEN UNTIL DRY STEAM APPEARS AND THE REVERSE LEVER SHOULD BE PLACED IN FULL GEAR TO INSURE FULL PORT OPENING TO THE CYLINDERS AND MAXIMUM STARTING POWER FOR THE LOCOMOTIVE AND LUBRICATION THE FULL LENGTH OF THE VALVE CHAMBERS.

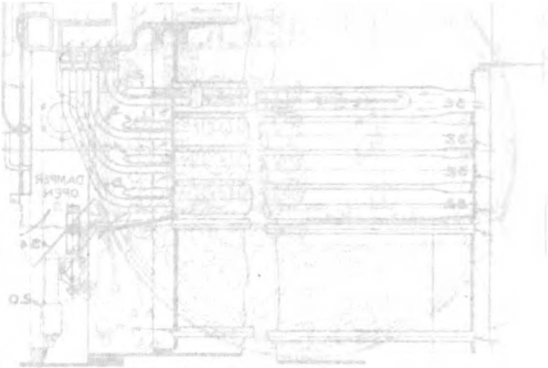
When water is carried over into the superheater, closing the throttle does not stop the supply of steam into the cylinders until the water in the superheater has been evaporated and used. This condition of water in the superheater causes trouble in spotting engines at water tanks, coal chutes, etc., in switching service and is especially bad in "hump yard" service on account of the lost time in "cuts." Ordinarily it is a sure sign of careless operation.

Water should be carried at the same level on a superheater locomotive as on a saturated locomotive, so that the superheater will receive dry steam.

High water will cause lubrication and packing troubles, lack of power, and slow running. It also increases the coal and water consumption, which reduces the economies that are available by the use of superheated steam.

Engines which do not steam freely should have dampers and flues examined to see that the damper operates correctly and that the flues are open and clean.

If the flues are open and cleaned and the damper operates cor-


DAMPER
OPEN
0.5
2.0

rectly, test the superheater and the steam pipes for leaks, the engine for blows and see that the draft appliances are in good condition.

Leaks of the superheater, steam and exhaust pipes, flues stopped up or leaking and the disarrangement of the draft apparatus, all interfere with the steaming of the engine and reduce the superheat by interfering with the flow of gases in the large flues. Blows in the cylinder and valve packing remove the oil from the wearing surfaces and cause excessive wear of parts, waste of steam and loss of power. When any of the above conditions exist, locate the one that is defective and if unable to make repairs on the line, report same on arrival at terminal.

If abnormal consumption of coal and water still continues and the above conditions do not obtain, go after the "Operation" and see that the superheater is used to superheat steam and not as an auxiliary to the boiler for evaporating the water.

Drifting

In drifting, sufficient steam should be used to insure the satisfactory distribution of lubricating oil and prevent the suction of dirt and gases from the smokebox into the steam chests and cylinders.

The lubrication of the cylinders should be constant and regular while the engine is working. Remember that it takes 7 or 8 minutes to get oil to the valve chambers after starting the lubricator when it has just been refilled. At other times the lubricator starts to feed promptly after setting the feeds. The lubricator should therefore be started in ample time to insure it feeding oil to valves and cylinders before starting to work steam.

Usually conditions of the valve stems and piston rods give a fair indication of the condition of the inside of the cylinder, i. e., a well lubricated piston rod means a well lubricated cylinder, while the reverse is also true. These indications are not always true when the swabs are kept in good condition.

The same amount of oil should be fed to the valves of a superheater engine as is fed to a saturated engine. When engines are equipped with oil pipes leading directly to the cylinders, feed two drops to the cylinders for each three fed to the valves.

Figs. 6 and 7 show the superheater damper cylinder arrangement. The cylinder being located on the side of the smoke arch just over the valve chamber. This arrangement is to permit of automatically completely closing the damper when there is no steam in the superheater units. The damper closes when the main throttle is closed and opens when the main throttle is opened. This design is to prevent heat from the fire going through the superheater flues when steam is not being used.

It should be understood that the steam passing through the units from the boiler to the cylinders prevent the units from becoming red hot, which is certainly the case when the damper is open and a bright fire burning, and the main throttle closed. It is the very worst condition for superheater units that can be produced, to have the heat from a hot fire passing around them and raising their temperature probably above that of red heat. Therefore, the damper must not be raised and then fastened in that position so that it will stay open when the throttle is closed.

The temperature of the steam leaving the superheater when the gauge registers 200 pounds boiler pressure, depends upon the efficiency of the superheater, the quality of steam delivered to the superheater and the temperature of the gases in the firebox, flues and superheater flues.

Assuming that the boiler flues are clean and that the water in the boiler is ordinarily clean and the temperature of the fire in the firebox is maintained at its maximum, the maximum degree of superheat can be obtained, and consequently the temperature of the steam leaving the superheater at this time will be at its maximum. The temperature of the steam leaving the superheater with 200 pounds pressure on the boiler, should be from 200 degrees to 250 degrees higher than that of the saturated steam in the boiler. For example, if an engine carries 200 pounds boiler pressure, the average temperature of the steam leaving the superheater should be about 600 degrees.

If, however, the firebox temperature is allowed to fall considerably below its maximum, due to firing the engine too heavy, or due to a very dirty fire or the admission of too much air through the fire or fire door; or if the flues containing the superheater units become stopped up, or if the water is carried so high in the boiler that a considerable quantity is carried over into the superheater with the steam, or if the water in the boiler becomes foul causing foaming which carries wet steam into the superheater, or if the draft plates or dampers are disarranged so that the heat from the firebox is not properly distributed; the temperature of the steam in the superheater will be considerably reduced below that obtained if none of these bad conditions exist.

The presence, therefore, of any of the above conditions which affect the performance of the superheater will cause its efficiency to be lowered in proportion as these faults exist.

Don't expect too much of the superheater. If quantities of water are passed through the superheater with steam, the units get very badly limed up inside. This not only restricts the flow of steam through the pipes but reduces their heating value. Don't carry the water in the boiler too high just because you do not hear or see any at the smoke stack. The superheater is intended to heat steam and not to boil water. The engine may be steaming well and still the full benefit may not be obtained from the superheater, as the engine may not be calling for the full capacity of the boiler. Do not work a very light throttle and long cut-off under these conditions.

The throttle on a superheater engine should not be closed entirely when making stops until the speed is quite low. The cylinder lubrication will be maintained much better if sufficient steam is used to prevent gases being drawn in through the nozzle or air being drawn in through the cylinder cocks. The throttle opening should be such that it will not provide an undesired power in the cylinders, but at the same time a sufficient amount will be admitted to properly follow the piston and as the speed reduces the amount of throttle opening should be reduced in proportion. Continue to use steam until the engine is close to the stopping point, or if not necessary to make a close stop, steam may be worked until the stop is nearly completed.

FRONT END AND DRAFT APPLIANCES

The proper and economical use of fuel depends to a large extent on the correct arrangement and maintenance in their respective positions of all parts of the drafting and spark arresting appliances. Given a fuel and a draft arrangement to get the best results from the fuel, it is then the enginemen's part in the proper combustion of fuel to see first that the locomotive is properly handled and performs the maximum amount of work from the steam produced, and that the firing is regulated in accordance with the requirements for steam. Experience shows that a locomotive to be drafted to the best advantage should be a free steamer and have a little margin as to steaming qualities. This can be had only when all draft appliances are in good order and the engineer and firemen

work in harmony with each other and with the work the engine is called upon to perform.

Three methods are employed to draw air into the firebox; the natural or stack draft, a mild forced draft, which is had by the use of a blower; and a stronger forced draft, which in the locomotive is produced by the exhaust steam escaping from the exhaust nozzle through the stack.

If the fire is clean the air will flow freely through the grates and sufficient air will be admitted to insure a complete combustion of the fuel. If the fire is clinkered or full of dead ashes, the air is held back and the locomotive lags for steam. A dirty fire causes an unusual pull on the fire door which tends to pull it shut.

The front end of a locomotive should be maintained absolutely air tight so that no air will be admitted to the smoke arch except that which passes through the grates and fire. Air admitted to the smoke arch tends to weaken the pull on the fire, or in other words, destroys the vacuum and diminishes the air supply to the fuel, causing a smoky, wasteful, slow buring fire instead of a bright hot smokeless fire. Air leaking into the smoke box many times causes fine cinders to burn there, which warps and burns the sheets.

Any steam leak, whether from steam pipes, exhaust pipe or nozzle tip joint, from superheater units or header, has precisely the same effect to weaken the draft action on the fire as air leaks admitted to the smoke arch; and a defect of this kind, no matter how slight, should not be permitted to continue after it has been discovered. They are all wasteful, annoying and progressive, that is, they get worse and like many other defects, can usually be most conveniently and cheaply remedied at the time they are discovered and before they have become a nuisance.

When difficulty is experienced on account of poor steaming with an locomotive that has established a reputation as a good steamer, or one which has been steaming properly for some time, the draft appliances should be examined. If they are found to be in good condition and in the same position they were when the locomotive was steaming properly, there is nothing to be moved; that is, we cannot move a thing that will improve the steaming qualities, something else is wrong and it should be located. The front end being in the same condition as when the locomotive was steaming well, cannot be improved and should not be disturbed. The engineer should determine if the locomotive is being properly handled and fired properly, that the grade of coal is such that no difficulty should be experienced if properly fired. The engine may be a good steamer and the method of handling or firing may be at fault.

General Arrangement of Front End Draft Appliances
Engines Equipped with Schmidt Superheater

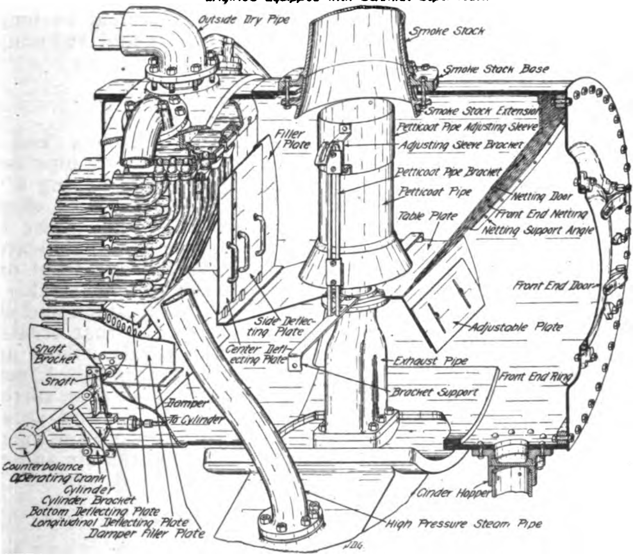


FIG. 8.

Fig. 8 shows the arrangement of a standard coal burning locomotive front end. Note the adjustable deflecting plate or diaphragm. This device is to baffle the draft currents so they will come into the firebox about evenly under all the grate area; that is, the fuel will not be consumed in the front of the firebox faster than at the back, and when this adjusting plate has been once set at the correct height to burn a level fire it should not be changed. In fact it cannot be changed to be of any benefit. If this plate be lowered the fire will burn more at the front of the box for the reason that lowering the plate covers more of the upper flues and concentrates the draft stronger through the lower flues, while raising the plates produces an opposite effect. It is clearly obvious then, that when a level fire is being maintained, the plate is doing all it can do.

The extension front end or smoke box shown in Fig. 8 differs from the older type in that more room is provided for the draft plates, netting and superheater elements.

Fig. 8 also shows the usual location of the petticoat or as it is often called, the lifting pipe, in the modern heavy locomotives. The petticoat pipe is considered as an extended stack, that is, it is practically an extension of the smoke stack into the smoke arch, and is usually of the same diameter as the inside of the stack.

There is not sufficient clearance for roundhouse doors, tunnels, bridges, etc., to permit the application of a long stack on top of the smoke box, and it has been found entirely practical to lengthen the stack by extending it into the smoke arch and reducing the height of the stack outside.

BLOWER

In order to provide a draft through the firebox and flues heavier than that of the natural draft of the boiler a pipe is connected to the steam space of the boiler in the cab, having a valve located in same for the purpose of controlling the flow of steam through the pipe. This pipe leads to the front end of the boiler and through the side of the smoke box, its end being located so that as steam passing through the pipe is discharged from one or more jets, the steam is blown up through the smoke stack. This action of the steam drives the air out of the smoke stack and smoke box, creating a draft much in the same manner as that created by the steam passing out through the exhaust nozzle. Such an arrangement is called a blower pipe, and is shown in Fig. 1, number 236. This blower is arranged as follows: A coil of pipe surrounds the nozzle tip, having a series of holes or jets so that as steam pressure is admitted to the coil from the blower steam pipe, the steam jets pass out the smoke stack drawing out the air and creating a draft.

GRATES AND ASH PANS

Fitted into the firebox at the bottom and attached to the mud ring is a frame which supports the fire grates. These fire grates are usually of the rocking finger type, about 12 to 15 inches wide. In a narrow firebox one section of grate is long enough to reach across the width of the firebox, as shown in Fig. 9.

Each section of the grate consists of a heavy shaft resting in the grate frame at each side, and having a series of fingers reaching out each side of the shaft. Extending below the grate is an arm which attaches to a rod extending back under the cab deck. This rod is connected to a shaker post reaching up into the cab, the shaker post is moved back and forth with what is called a shaker bar, so constructed that it can be fitted to the shaker post. As the shaker post is moved back and forth, the connecting rod leading to the grates is also moved back and forth, carrying with it the arm attached to the grate, causing the grate fingers to be rocked up and down. A sufficient number of these grates are applied to reach from one end of the firebox to the other. The fingers of the grates being so located that the grates set close enough together that the fingers of adjacent grate sections are interposed but without touching each other. The system of grates being all connected to the connecting rod. A locking arrangement is provided in the cab for securing the shaker post in position when the grate fingers are all in their normal or level position. See that the grates are level and the lock is used after shaking, if the grates are not level the fire falls through badly and the fingers on the grates will be burned off.

At one end of the firebox is what is called a dump grate, this

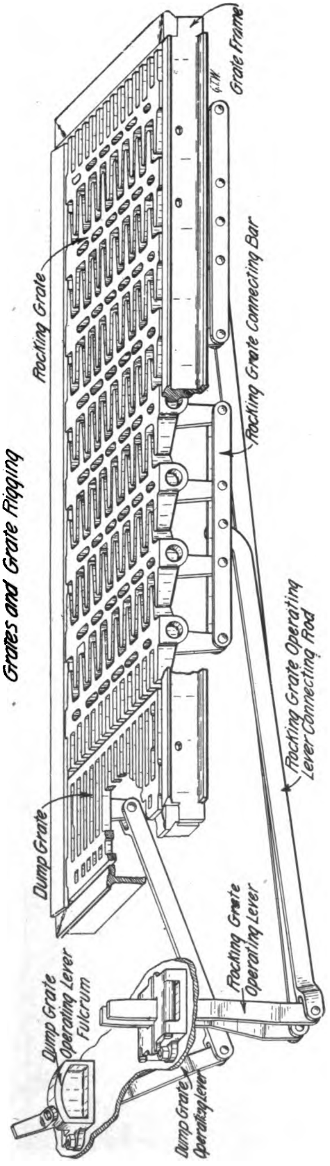

Grates and Grate Rigging
Grate Frame
G.T.W.
Rocking Grate
Rocking Grate Connecting Bar
Rocking Grate Operating Lever Connecting Rod
Dump Grate
Rocking Grate Operating Lever
Dump Grate Operating Lever Fulcrum
Dump Grate Operating Lever

FIG. 9.

grate is usually of the same width or wider than are the rocking grate sections. This grate, however, has its shaft located at one side instead of in the center, so that if it is allowed to drop down an opening equal to the width of the grate would be provided, in the same manner as an ordinary trap door. This grate also has an arm extending underneath which is attached to a connecting rod leading back under the cab deck, and a post or shaft provided so that this grate may be raised or lowered. The purpose of this grate is to provide an opening large enough to permit of clinkers and other refuse being cleaned out of the firebox in case such refuse cannot be disposed of by shaking the rocking grates.

In some cases engines are equipped with what is called a table grate. This grate is similar in construction to the finger grate, with the exception that the fingers, instead of being interposed, are shortened, placed closer together and are united at the ends by a web extending the full width of the grate section. The grate being flat on top resembles a small table, about 12 to 15 inches wide, and long enough to reach between the grate frames. These grates are set in their frames so that the edge of each grate just clears the next one, the entire system of grates all being connected to the connecting rod and shaker post, and rocked in the same manner as the finger style of grate.

For large wide fireboxes it is impractical to provide grates long enough to reach the entire width of the firebox, consequently a supporting frame is placed lengthwise of the firebox at the center. A system of grates is then installed on each side of the center frame, as shown in Fig. 10.

In order to reduce the difficulty of shaking the grates, half the grates on one side are connected to a connecting rod and shaker post, and the other half on the same side being connected to another connecting rod and shaker post. The grates on the oposite side are connected up in this same manner, so that when shaking the grates the fireman is required to rock only one-fourth of the total number of grates at one time.

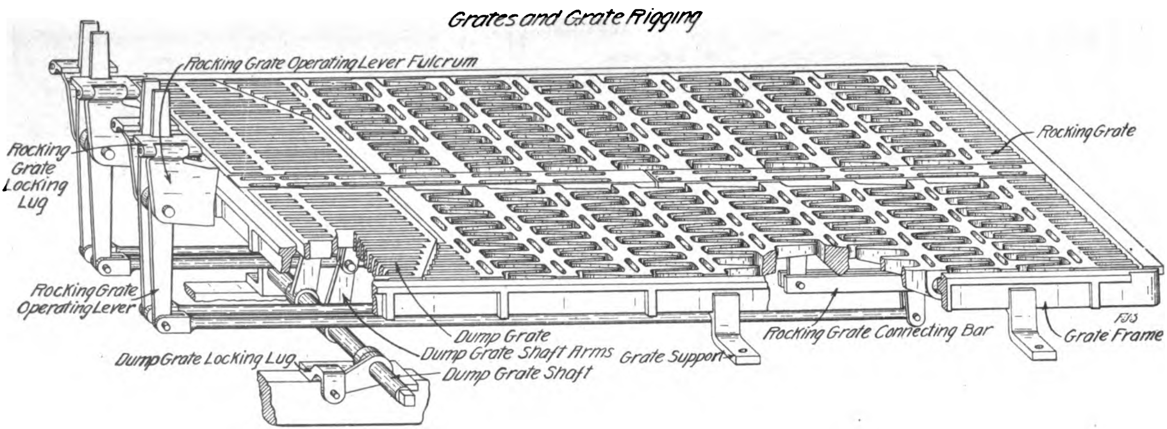

Grates and Grate Rigging
Rocking Grate Operating Lever Fulcrum
Rocking Grate
Rocking Grate Locking Lug
Rocking Grate Operating Lever
Dump Grate
Dump Grate Shaft Arms
Dump Grate Locking Lug
Dump Grate Shaft
Grate Support
Rocking Grate Connecting Bar
Grate Frame
FJS

FIG. 10.

ASH PANS

Below the grates is the ash pan, which serves to catch fire and cinder falling through the grates. This pan is in some cases provided with dampers to control the amount of air admitted to the firebox from underneath. It is also provided with openings in the bottom through which the ashes may be dumped when it is desired to clean the ash pan.

Figs. 11 and 12 show ash pans commonly used on locomotives.

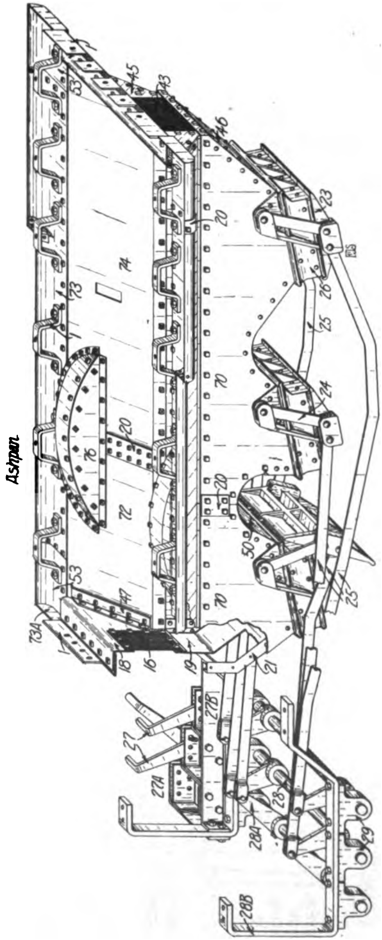


FIG. 11.

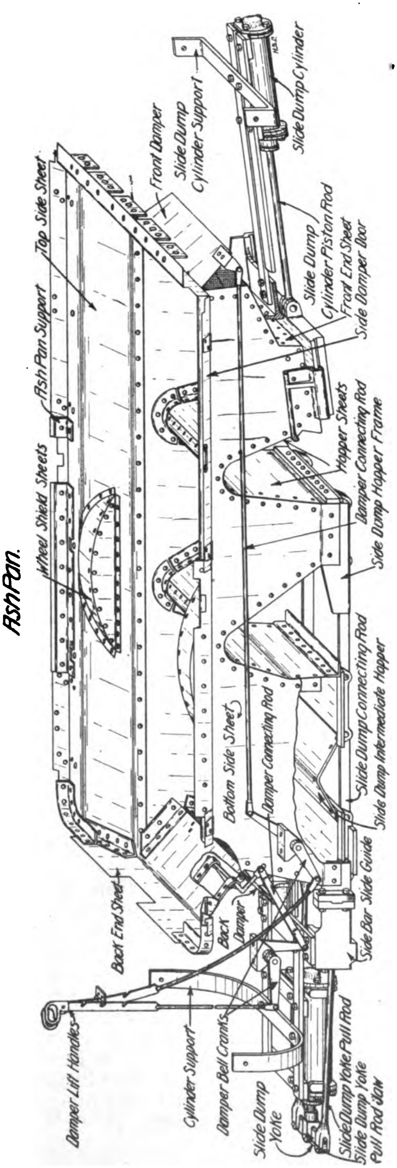

Ash Pan.
Slide Dump Cylinder
Front Damper
Slide Dump Cylinder Support
Top Side Sheet
Slide Dump Cylinder Piston Rod
Front End Sheet
Side Damper Door
Ash Pan Support
Wheel Shield Sheets
Hopper Sheets
Damper Connecting Rod
Side Dump Hopper Frame
Slide Dump Connecting Rod
Slide Dump Intermediate Hopper
Bottom Side Sheet
Damper Connecting Rod
Side Bar Slide Guide
Back End Sheet
Back Damper
Damper Lift Handles
Cylinder Support
Damper Bell Cranks
Slide Dump Yoke
Slide Dump Yoke Pull Rod
Slide Dump Yoke
Pull Rod Jaw

FIG. 12.

In Fig. 11 the slides for dumping the ash pan are operated by hand, while in Fig. 12 these slides are operated by air pressure. Care should be taken after dumping the ash pan to make sure that the slides are properly closed and where they are operated by hand that the locking pins are applied to hold the slides in a closed position. Do not allow fires to burn in the ash pan. If a quantity of burning coals are allowed to remain in the ash pan without wetting down, the metal sheets are badly burned and warped, it is therefore advisable to wet down the ashes in the ash pan if much fire is present and it is impossible to dump the ash pan at that time. Do not hammer the sides of the ash pan viciously with the shaker bar or coal pick, this bends the sheets out of shape and loosens the joints so that the ash pan drops fire. See that ashes are kept pushed down into the pan and do not allow an accumulation of ashes around the edge of the pan at the mud ring. This shuts off the air supply and affects the steaming qualities of the engine.

FOAMING AND PRIMING

Priming is caused by too much water in the boiler. Foaming may be confined to the surface of the water, in which case it is formed by the bursting of small steam bubbles, or due to an excess of certain alkaline salts the steam bubbles may form and grow far below the surface of the water to such an extent that the column of water swells and fills the entire boiler.

When foaming occurs the quickest way to stop it is to ease off on the main throttle and start the injector. If the glass shows sufficient water, begin blowing out from both sides, holding each blow-off cock open alternately for about three seconds, and closed for about five or six seconds. Continue this so long as steam and water can be maintained until the engine can again be worked to full capacity. If steam and water cannot be maintained there is only one thing to do and that is to stop and change the water in the boiler, or as much of it as can be safely done, give it time to settle and then start the train as easily as it can be handled, opening cylinder cocks to free cylinders of water. Don't force the engine faster than the foaming conditions will permit or foaming will recur.

USE OF BOILER COMPOUND

Foaming compound should be used in time to prevent foaming, in fact on foaming water districts foaming should be anticipated by the use of foaming compound in quantities as prescribed for that territory. This should be done before foaming commences, and when compound has been applied, the water in the tank and boiler should be under treatment continuously, the former by applying compound every time water is taken, and the latter by working the injector continuously while the engine is working. In this way a continuous supply of compound to the boiler is maintained. With the compound used as above, and the blow-off cocks used at convenient intervals, it will require extraordinary bad conditions to cause a complete failure from foaming.

USE OF BLOW-OFF COCKS

When using blow-off cocks with engine standing, the boiler should not be filled up and then blown out. The principle that should govern in blowing out a boiler to prevent foaming is that the foul water in the boiler should be gotten rid of and replaced with cleaner water which is the water in the tank; and as it is the foul water in the boiler that should be blown out it is a gain to blow it out without diluting it. Do not fill boilers full of water and then blow out as much as can be spared by holding the blow-off cocks open continuously. Filling boiler full of water at one time when water is low causes great differences in temperature between the lower and upper parts of boilers, and the liability of starting flues and staybolts leaking is greatly increased. When using blow-off cocks hold them open for about three seconds and allow them to remain closed about five or six seconds, repeating this operation until the desired amount of water is blown out.

When the boiler is foaming, or it is thought it is getting near the foaming point, and a stop is made, use both blow-off cocks working intermittently, and blow out as much water as can be spared down to an inch or half an inch of the bottom of the water glass. If it is necessary, on account of the boiler popping, to cool it by using the injector a little, that is the proper thing to do, but do not inject several inches of water into the boiler at one time unless the engine is working.

Blow-off cocks, as stated, should be opened intermittently from both sides if possible, and should be held open not more than about three seconds at each opening, with about five or six seconds interval between each opening. The reason for this is that is is the water in the water leg and lower parts of the boiler which is heavily charged with the suspended matter that we want to get rid of, and the opening of the blow-off cocks at intervals gives time for the sludge to collect again around the blow-off cock opening in the boiler. If it is held open for long periods a column of water forms from the upper parts of the boiler which holds back the water on each side of this column.

In foamy water districts blowing out should be started at the beginning of the trip. A modern boiler holds about 4,000 gallons of water, which, when heated to steam making temperatures, parts with a large percentage of its solids; in fact precipitation of the most refractory solids occurs at 260 degrees, so that the incrustating solids of 4,000 gallons of water have been precipitated as sludge before the engine is moved. Opening the blow-off cocks a few times at convenient intervals at the beginning of the trip discharges a large percentage of this sludge, and also proves that blow-off cocks are in good working condition. In foamy water districts the maintaining of boilers free from sludge insures much better performance and greater freedom from foaming for the reason that when sludge, or suspended matter, is present in the lower part of a boiler, any rough handling or unusual hard work has a tendency to disturb it and cause it to raise and mix with the water above it. This almost invariably precipitates foaming, which will continue until the suspended matter is settled again or is

blown out. The amount of water to be blown out is much less if the blowing out is started early, than is the case if no water is blown out before foaming actually begins. The engineers should know the peculiarities of the water on his division, and where the water is liable to start foaming, and he should prevent foaming, which he can certainly and easily do by free use of the blow-off cocks, keeping the water in the boiler free from suspended matter, and under the influence of compound.

Experience shows that when the locomotive is standing and it is necessary to increase the water supply in the boiler, not more than one-half inch should be injected at one time, or just sufficient to insure its safety. Water should be supplied if possible when locomotives are moving to or from a train, or while it is hauling a train. No chances should be taken of damaging the boiler on account of low water, but it is expected, that knowing the proper way to use an injector, it be used in that way whenever conditions will permit; and any engineer, fireman or hostler who accustoms himself to using the injector only when the engine is working, unless he absolutely has to, will find that there are very few occasions when it will be necessary to vary from this practice.

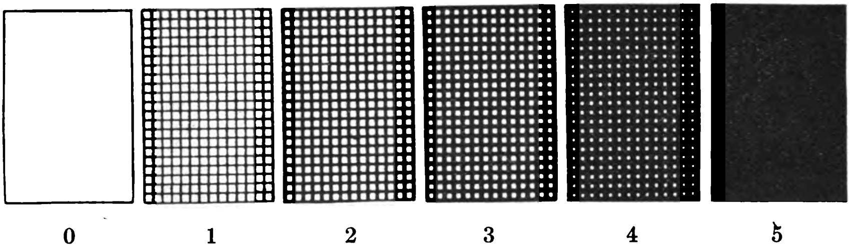
ARCH AND CIRCULATING TUBES IN LOCOMOTIVE FIREBOXES

Fig. 1 also shows the general location of arch tubes in a locomotive firebox. While the arch tubes are designed to support the brick arch its function is primarily a circulation tube to convey the cooler water from the lower parts of the boiler to the upper parts. As the water in the tube absorbs the heat from the fire it becomes impregnated with steam bubbles, expands and becomes lighter and as it becomes lighter ascends through the tube and circulation is established. As the hot water passes through the tubes it is replaced with cooler water from the lower parts of the boiler.

The brick arch in a locomotive firebox acts as a balance to equalize the heat by absorbing it at the hottest period between fires and releasing it while the door is open and fresh fuel is being applied. The high temperature of the arch serves to ignite gases and other products of combustion which would otherwise escape as black smoke. The location of the arch causing as it does the flame to pass from the front to the back of the firebox, produces a more thorough mingling of the combustible elements, and more complete combustion. At the same time it prevents cold air being drawn into the flues during the process of firing. The air entering the fire door, coming into contact with the arch is heated before entering the flues.

COMBUSTION

The railroads burn approximately 25 per cent of the bituminous coal produced in the United States, and coal tonnage approximates about one-third of the combined freight traffic of all the railroads. The fuel bill for this Company alone is more than $20,000,000.00 annually. This emphasizes the necessity for a proper interest and effort toward fuel saving.



The Ringlemann Scale for Grading the Density of Smoke

Fig. 13.

The Ringlemann chart showing smoke density should be studied by enginemen. Numbers 0, 1 and 2, indicate good fuel performance. The numbers 3, 4, and 5, indicate poor, and when either, especially 4 and 5 show at the stack, it is either a case of poor firing or a defective locomotive. The fact is, good firing and good conditions will rarely show as dark as No. 2.

Three things are essential to the proper combustion or burning of fuel in a locomotive firebox. They are, the fuel to be burned, the oxygen which is a supporter of the combustion, and the igniting temperature of the fire. The latter being necessary to expell the gases contained in the fuel in order that they might unite with the oxygen in the air. In order then to provide for proper combustion it is necessary that a fireman be familiar with the elements contained in the atmosphere, and the various fuels, and in a measure concentrate his attention upon the relation of fuel, oxygen and igniting temperatures.

Oxygen is a part of the air, representing about one-fifth of it by volume. In order to obtain an ample supply of oxygen for the proper combustion of the fuel placed in a firebox, it is necessary to draw through the fuel bed a quantity of air which is equal in volume to five times the volume of the oxygen required. This must be acomplished through the action of the draft through the smoke box and flues; and in order to permit it to be accomplished, it is

necessary to provide sufficient openings through the ash pan and grates, and keep the fire in a condition that will permit free passage of air through the entire fuel bed on the grates.

The process of burning fuel in a locomotive firebox is the uniting of oxygen, which is a gas, with the gases contained in the fuel. In order to cause the gases in the fuel to mix with the gases contained in the atmosphere, it is necessary that the firebox temperature be sufficiently high to cause the gases to be expelled from the coal. When the coal comes in contact with heat, if the firebox temperature is from 1,300 to 1,800 degrees the gases in the coal will be expelled and mix with the oxygen contained in the atmosphere. When these two gases unite under these conditions, heat is evolved and used in generating steam. If a sufficient supply of oxygen is present, a pound of carbon will burn to form a colorless gas called carbon-dioxide, and enough heat will be evolved to convert 12½ pounds of water into steam, the water to begin with being at a temperature of 32 degrees. If, however, the supply of oxygen is insufficient, then another colorless gas will be formed, called carbon-monoxide and only four pounds of water will be evaporated under similar conditions, that is, with the same carbon to be burned one may get its full heat value, or less than one-third, depending upon the supply of oxygen.

ADMISSION OF AIR TO FIREBOX

A simple demonstration to prove the indispensibility of air or oxygen to the combustion of carbon may be made by lighting a match and inserting same in the neck of an inverted bottle. You will find that after the match enters the bottle the flame will die down, and withdrawing the match causes it to light up again. Another method is to close up the air openings in an ordinary lantern, this will cause the flame to smoke badly and finally go out.

Care should, of course, be taken that to much air is not admitted to the firebox by allowing holes to form in the fire. This tends to rob the balance of the grate area of its share of the air and permits the gases to be carried out of the firebox unconsumed. Air admitted through a hole in the fire is relatively cold and chills the firebox sheets and flues. Clinkers will be formed if coal is placed over the bare spots on the grates. It is possible, of course, to admit too much air if the fire is too thin, or by leaving the firebox door open if the engine is working.

The air openings in ash pans should equal or exceed 14 per cent of the grate area. The grates used for burning bituminous coal should have openings of approximately 40 per cent of their total area. Defects in the grates or grate rigging, or excessive lost motion in the latter, should be reported promptly, to keep these parts in good repair. Remember that for each one shovel full of coal saved you are lessening your labors about three-fourths of one per cent per ton of the coal handled. Remember also that every man connected with the operation of trains is either a saver or waster of fuel.

In order to obtain the best results in firing, the firebox temperature should be maintained as high as possible, or at the temperature that would be produced by a white hot fire. Under conditions where a proper fire is being maintained it is impossible to admit too much air through the fire.

Do not use more water in wetting down coal than is necessary to keep down dust. With fine coal, wetting it down tends to prevent too much fine coal being drawn out through the stack, the dampened dust adheres on the lumps of coal, and is not so readily drawn out through the flues.

FIRING PRACTICE

In practice the fireman should cultivate the habit of proper and regular firing. He should learn to fire as lightly as possible and maintain an even fire, scattering the coal as thinly over the grate surface as conditions will permit, opening and closing the door between each scoop of coal. Do not take it for granted that because it is necessary at times to fire the engine seemingly heavy, such as might be the case in ascending grades with heavy trains, or where the engine is being worked unusually hard for some particular reason, that there is not a large percentage of the time that the engine may be fired much lighter. The fact is, that in most localities the engine may be fired regularly and lightly for a greater part of the distance over a division. To obtain the best results the engine should be fired as light as possible under all conditions, and as regularly as possible, maintaining as thin and as clean a fire as the conditions will permit.

The chart, Fig. 14, is an example of irregular firing. This illustration is by no means representative of an isolated case, but is frequently observed in ordinary service. It will be noted that the scoops of coal per fire varied from five scoops in one instance to eighteen scoops.

The result of placing large quantities of coal in a firebox at one time causes a greater quantity of gases to be liberated from the fuel than can properly mix with the oxygen passing up through the grates. Some of these gases pass off unburned, and when large quantities of coal are placed in the firebox, as indicated by this chart, it is impossible to properly liberate and burn the gases expelled. For example, if a scoop of coal is thrown in one pile on a hot fire the gases around the edges are driven off quickly, a little later the gases throughout the shovel full of coal are gradually expelled and burned. If, however, another scoop of coal is thrown on top of the first one before the gases have all been expelled, it simply smothers the gases under the second shovel full, causing a part of the coal to remain unburned. It also shuts off the free flow of air through the fire, causing more or less coking and clinkering of the coal, which later on contributes to the labor and annoyance of the fireman, which could have been prevented had he avoided bringing about such a condition.

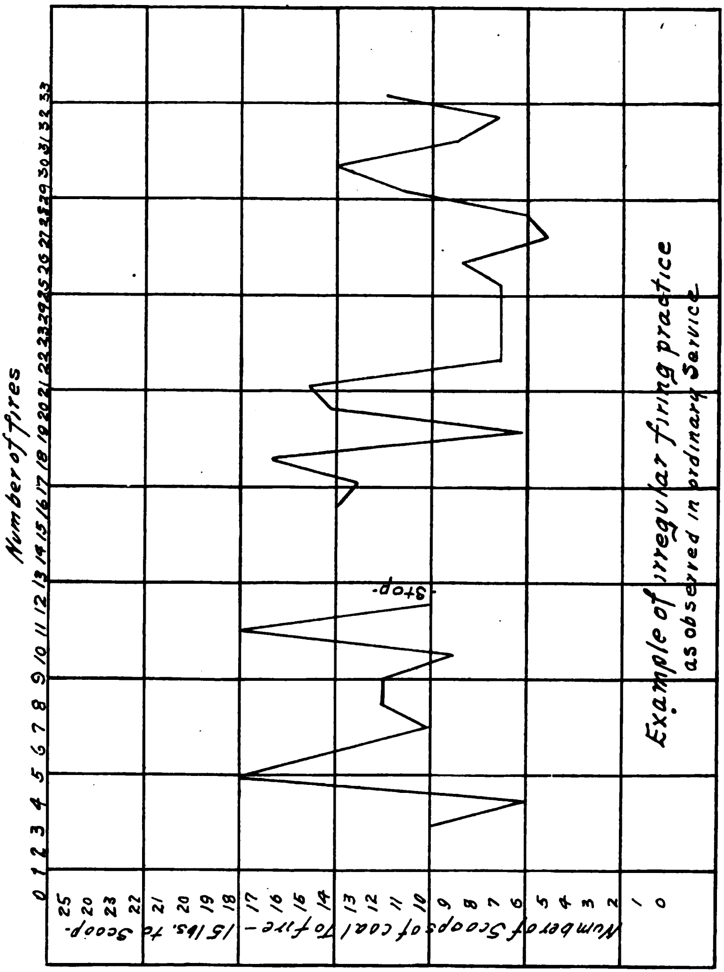

Number of fires
Number of Scoops of coal to fire - 15 lbs. to Scoop.
Stop.
Example of irregular firing practice
as observed in ordinary Service

FIG. 14.

PREPARATION OF FIRE

The fireman should see that the fire is properly prepared before starting, and avoid forcing the fire too much with the blower to bring about this condition. The fire should be built up gradually by scattering the coal evenly over the grate surface and in light quantities. He should also see that he has proper tools and appliances to care for the fire on the road, that the grates are in proper working order. The grates should not be shaken too soon after leaving a terminal, the idea being to allow a slight accumulation of ash next to the grate, if possible, before they are shaken at all. The first time the grates are shaken, they should be shaken very lightly.

USE OF BLOWER

The use of the blower with the firebox door slightly open when the engine is standing or drifting is successful in preventing black smoke to a large extent. The blower should be used only heavy enough to clear up the smoke. One thing essential in reducing black smoke and securing economy in the use of fuel is for the engineer and fireman to work in harmony and co-operate with each other at all times. The engineer should realize that good results in the prevention of black smoke and also that proper firing cannot be obtained unless he works the engine as economical as possible, and keeps the fireman fully informed of changes that he can anticipate in the working of the engine. With the engine free from leaks and blows, and properly drafted for good steaming, there is no good reason why fuel consumption and black smoke cannot be reduced to a minimum.

APPROACHING STOPS AND TERMINALS

In approaching stations or other points where stops are to be made, the fire should be burned down to prevent excessive black smoke. The emission of clouds of smoke when drifting is very annoying and discomforting to passengers and should not be permitted. On arrival at terminals the fire should be thoroughly burned out. Do not leave engines with heavy fires banked with "green" coal. The fireman should, on approaching terminals, endeavor to burn out all banks in the fire and have the fire in such condition that it may be cleaned without necessitating dumping large quantities of "green" coal.

It must be remembered that more than half the fuel consumed in a locomotive firebox is consumed as gases, and in this connection it is well to remember also that when these gases are evolved they do not loiter in the firebox in order to be burned, but hasten at once toward the stack. Therefore, if these gases are being liberated from the fuel in quantities greater than can be properly mixed with the oxygen passing up through the grates, some of the gases will escape unburned. Heat is thus expended in breaking down the coal and liberating the gases and then the best part of the fuel is simply thrown away.

When a fireman produces black smoke he does so because he is only partially burning the hydro-carbon gases and in proportion to the density and amount of black smoke passing out the stack will he be required to place more coal in the firebox. In other words, if he could maintain the steam pressure by making very little or no smoke, the amount of coal to be placed in the firebox would be considerably less than is the case where great quantities of smoke are produced. Black smoke is unburned carbon, mixed with a very high percentage of combustible gases and it therefore represents a considerable part of the coal that is valuable for heating purposes. It is also an indicator pointing to a loss. There is always a tendency toward loss of fuel in heavy firing on account of the large amount of gases expelled from the coal, and the temporary stoppage of the circulation of air through the fire just at the moment the gases are being expelled. Lighter firing and scattering the coal well over the grate surface maintains a better circulation of air through the fire, the gases are expelled from the coal in smaller quantities, which provides for a better mixture of air with the fuel gases. To secure proper combustion of the gases expelled from the coal they must be mixed with sufficient oxygen immediately upon being evolved in order to burn properly.

While it is impractical to maintain absolutely perfect combustion in a locomotive firebox, due to the manner of supplying the fuel at irregular intervals, and in varying quantities, variation of grades, loads, and speed, which requires a variation in the amount of steam used and consequently fuel consumed; it should be possible to evaporate eight to ten pounds of water to one pound of bituminous coal burned. Bituminous coal contains about 70 to 80 per cent carbon, 5 per cent hydrogen and the remainder may be classed as waste material or incombustible matter. Ordinarily it requires twelve to eighteen pounds of air to supply the amount of oxygen to consume the gases expelled from one pound of soft coal. A pound of air occupies a space of thirteen cubic feet. Taking twelve pounds of air, the lowest rate of air consumption for one pound of coal, multiplying by 13 cubic feet gives 156 cubic feet of air used for each pound of coal burned. Ordinarily this would require about 30,000 cubic feet of air for each ton of coal burned. The above emphasizes the necessity of unrestricted air admission through the grates. Anthracite coal contains a higher per cent of carbon than bituminous coal, and burns with a much smaller flame, because more of the total composition of the coal is consumed as carbon.

When the fire becomes too heavy or is clinkered, which of course brings about a low temperature in the firebox, or on account of there not being sufficient air admitted through the fire, the fire will not burn to a white heat, a fire in such condition is usually termed a red fire. It is generally impractical to attempt to regulate the amount of air admitted to the firebox by opening the firebox door. If the supply of air admitted above the fire could be exactly regulated by opening the firebox door, it would many times serve a very useful purpose. However, air admitted through this source is not sufficiently distributed among the fuel gases to produce proper combustion, and being admitted in a cold state it chills the firebox flues. Keeping the fire clean and admitting

plenty of air through the grates will provide a proper mixture to burn the gases as they are expelled from the coal. Holes through the fire door and the use of a deflecting plate tends to protect the door from the excessive heat of the firebox and also admits a small quantity of air above the fire to assist combustion immediately after placing fresh coal upon the fire.

RULES FOR THE GUIDANCE OF ENGINEERS, FIREMEN, HOSTLERS AND OTHERS WHO HANDLE OIL-BURNING LOCOMOTIVES

IN CASE OF ACCIDENT, DERAILMENT, FIRES, ETC., CLOSE OIL SAFETY VALVE BY JERKING CABLE AND PULLING PIN OUT OF ROD, WHICH WILL ALLOW VALVE TO DROP ON SEAT. THIS WILL PREVENT OIL FROM RUNNING OUT, AND LESSEN THE DANGER OF FIRE.

The firing of an oil-burning locomotive differs very materially from the firing of a coal-burning locomotive, and more careful attention is necessary in oil-burning than in coal-burning to render the combustion economical. Firing an oil-burner demands that close attention be given at all times in order to produce satisfactory results. To this end the fireman and engineer must work together, and every time the engineer changes the throttle or reverse lever the fireman must change the fire. In fact, a good fireman on an oil-burning locomotive must be watchful and diligent, for he can save or waste more than he could on a coal-burner.

The conditions are such that no arbitrary instructions can be given as to how much steam should be used for the atomizer, how much the dampers should be opened, or the exact temperature to which the oil in the tender should be heated. These details must be left to the intelligence of the engine crew, and their experience should indicate the adjustments necessary under various conditions. In connection with oil-burning, however, the following general rules are imperative, and must be observed in detail:

FILLING OIL TANKS

Do not carry or permit any one else to carry oil lamps or oil torches within a distance of ten feet of any oil tank opening.

Incandescent lamps or pocket flash light only should be used around oil tank manhole when taking oil.

Before taking oil see that the screen or strainer is properly in place in the manhole. A tender oil tank should not be supplied with a greater quantity of oil than will fill it within two inches of the top as the oil expands considerably when heated and may overflow.

When taking oil and after the valve to the spout has been closed, allow the spout to drain before moving it from the manhole. Spouts provided with drip pans or other receptacles to prevent loss of oil should have same properly applied before the spout is moved away from the manhole. Careful attention to these matters is necessary in order to prevent waste of oil and to prevent oil from being spilled on top of the tank as enginemen, trainmen, and others slip and fall while walking over the top of the tank if it is oily.

After the tank has been filled, clamp the manhole cover down and keep it there until it is necessary to take another supply of oil. Under no condition should the manhole be left open except when the tank is being filled with oil.

MEASURING OIL

In measuring the amount of oil in a tank by means of the measuring rod and a torch or lantern, take the measuring rod to the light to examine it; do not take the light to the tank. When wiping the rod see that threads of waste do not adhere to it as they will finally reach the valves, clog them and interfere with oil distribution. After wiping do not drop waste on top of tank. It may be blown into the oil tank. Do not allow waste to collect on the oil tank under any circumstances.

USE OF OIL HEATER

The oil should be kept warm enough to flow freely at all times. Best results are obtained when the oil is heated just enough to cause it to flow to the burner freely, but no hotter. If too high a temperature is maintained, some of the oil is driven off in the form of inflammable vapors and is lost. These vapors greatly increase the risk of fire and explosion and interfere with the steady flow of oil to the burner. The temperature to which the oil should be heated depends somewhat on the nature of the oil. Thick, heavy oils must be kept hotter than thin, light oils. As a rule the oil should be heated until the sides of the oil tank feel warm to the hand or until the bare hand can be held in contact with the feed pipe under the deck without much discomfort. Under these conditions the temperature of the oil will be about 112 degrees.

The oil heater should be placed in operation sufficiently in advance of firing up an oil-burning locomotive to insure a steady, free flow of oil to the burner when the fire is lighted.

When oil-burning engines or their tenders are held out of service during freezing weather, the oil tank heaters should be drained and thoroughly blown out with air to prevent damage to the coils from freezing.

Heaters should be watched closely to detect leaks. Oil discharged with exhaust steam from the heater, or excessive accumulations of water in the oil tank are evidences of a leaky heater.

Heaters that are found to be leaking should be repaired promptly.

STARTING FIRE

In firing up dead oil-burning locomotives, steam from the roundhouse blower line or some other outside source is required for operating the heater, atomizer, and blower. All of these appliances can be supplied with steam by connecting the roundhouse blower pipe to the blower fitting on the side of the smoke arch or just in front of the cab. As soon as steam pressure of 20 lbs. has been generated in the locomotive boiler, the oil burning appliances may be operated with the locomotive's own steam and the roundhouse blower pipe may be disconnected if desired.

In starting a fire in a locomotive having 20 lbs. or more of steam the oil burning appliances may be operated entirely with steam from the locomotive boiler and no connection with the

roundhouse blower line is necessary. In case difficulty is experienced in getting oil to flow from burner when firing up, it may be overcome by applying burning waste outside of pan to warm burner.

The following precautions should be carefully observed when starting a fire in an oil-burning locomotive:

(a) See that the boiler is properly filled with water. The water glass alone should not be relied upon to determine this but the gauge cocks should be opened to see that water runs out.

(b) Examine the interior of the firebox to see that the brick work is in suitable condition, that the draft pan has been properly cleaned out since last trip and that the floor of the pan is free from accumulations of carbon, loose bricks or other obstacles that might obstruct the free passage of the atomizer jet from the burner to the flash wall.

(c) See that the steam and oil openings in the mouth of the burner are not clogged up. Obstructions in the oil passage of the burner may be blown out by opening burner blow out valve No. 3 and keeping the firing valve No. 7 closed. Obstructions in the atomizer opening, which cannot be blown out by opening the atomizer valve No. 2 wide open must be removed with a knife blade or some other thin strip of metal that can be inserted in the narrow opening. It is important that this opening be entirely free from obsructions in order that the atomizer jet may have a perfect flat, fan-like appearance.

(d) Immediately before lighting the fire see that no one is working under the engine near the firebox.

(e) When everything is ready for lighting the fire, open the dampers and put on the blower strong enough to create the necessary draft; open the atomizer valve and blow out any water that may have condensed in the burner and pipes; close the valve and throw a bunch of burning waste directly in front of the burner. Old scrap cotton waste should be saved for this purpose. The burning waste should not be placed within two feet of the mouth of the burner. Next close and fasten the fire door, leaving the "peep" or sanding hole open so as to observe the fire; turn on the atomizer strong enough to carry oil from the burner to the burning waste and then open the firing valve No. 7 slowly and cautiously until ignition of the oil takes place. After ignition of the oil has been established and the fire is burning steadily, the atomizer and firing valves should be opened wider so as to carry the combustion back to the flash wall. At first when the brick work is cold only a light fire can be maintained but later as the brick work becomes heated the fire can be increased as desired. When firing up an oil-burning locomotive it is particularly important to see that all of the oil passing through the burner is consumed in the draft pan and that none of it drips down into the pit or on the ground under the engine, as an accumulation of oil under the firebox is likely to cause a serious fire.

The combustion in the firebox should be observed through the peep hole, and under no condition should the fire door be opened while the fire is burning. A fire having a bright clear color denotes proper combustion while a dull red smoky flame indicates the reverse.

Fires in oil-burning locomotives standing in roundhouses, on side tracks, or at terminals, should be carefully watched to see that the fire does not unexpectedly go out. It is particularly important to look out for this when engines are being fired up as, when the brick work is comparatively cool, the fire is more likely to go out than when the bricks are fully heated.

If the fire does go out, the firing valve must be closed at once to prevent oil from escaping and collecting in the pit or on the ground under the engine where it would be likely to catch fire when the fire is relighted. In case a considerable quantity of oil collects under the firebox of an engine having a fire in it, the accumulation of oil should be promptly covered with sand or the engine should be moved far enough to eliminate danger from fire.

In relighting fires which have gone out or have been put out, a bunch of burning waste should be thrown into the firebox and fire door fastened shut, as has been described, before the firing valve is opened. No attempt should be made to relight the fire from the heated brick work. The practice of doing so is dangerous and is strictly forbidden, as it frequently causes explosions which damage the brick work and may result in severe personal injury to parties on or near the locomotive.

If the fire has been extinguished but a short time and the brick work is still hot or even warm, the blower should be used to clear the firebox and smoke box of explosive vapors before any attempt is made to relight the fire.

In firing up where steam is not available, wood may be used until twenty pounds of steam is generated in the boiler (less than this pressure will not be sufficient to atomize the oil). The wood must be placed in the firebox with great care, so as not to damage the brick work or burner. Wood used for this purpose should all be consumed before engine is allowed to leave the terminal. Oil-burning engines which have been fired up with wood should be started carefully on leaving terminal to prevent sparks from setting fires along the right of way.

On locomotives equipped with back end burners place a piece of sheet iron in front of the burner to protect it. The wood should be placed on top of the arch and care should be taken not to damage the arch when throwing in wood. Before the oil is turned on, this shield should be removed from in front of the burner.

HANDLING ENGINES AT TERMINALS

The throttle should not be opened to move an oil-burning locomotive unless there is a steady and reliable flow of oil to the burner and the fire is burning satisfactorily. If this precaution is not taken, the fire is likely to be put out by the exhaust. When moving an engine care should be taken not to slip the drivers, pull the throttle open suddenly, or produce a sudden strong exhaust in any way. This is particularly necessary when no one is at the firing valve as the sudden, unusual draft produced may put out the fire.

When the engines are to be left standing under steam (on side tracks, etc.,) care should be taken to see that the fire does not unexpectedly go out, permitting fuel to escape and creating a

dangerous fire hazard. In the interests of safety and fuel economy it is considered desirable that engines left standing under steam should have fires put out and dampers closed except at regular intervals when the hostler or watchman can be present long enough to fire the engine sufficiently to keep it alive.

A good strong fire should be maintained while working the injector on engines standing under steam and under no circumstances should an injector be put on when the fire is out.

When getting engines ready for service, hostlers should see that the fuel oil is heated sufficiently and should see that all water in the oil tank is drained out.

Oil-burning engines at terminals should be taken into the roundhouse and have fires put out as promptly as possible in order to save fuel and to avoid the fire hazard connected with holding engines under steam. Care should also be taken to avoid holding outgoing engines under steam longer than is absolutely necessary.

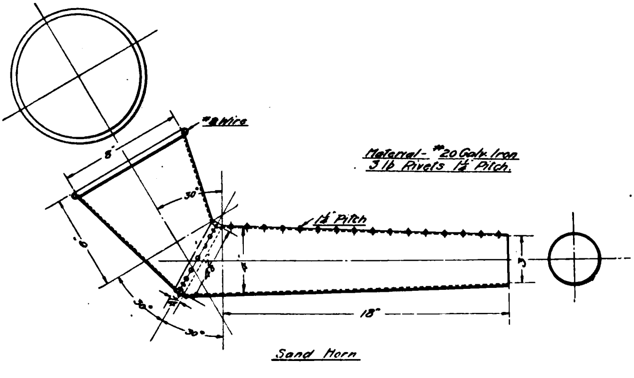


FIG. 15.

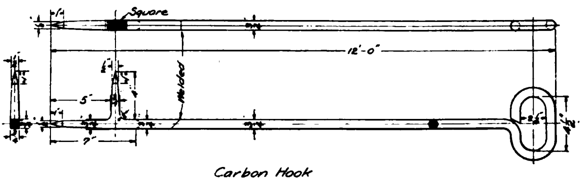


FIG. 16.

When putting out the fire in an oil-burning locomotive for the purpose of killing the engine or preparatory to leaving the engine standing for some time without the attention of a hostler or watchman, the safety valve No. 11 in the oil tank must be closed first and the firing valve left open, to allow the oil in the feed pipe to be burned. After all of this oil has been consumed, the firing valve No. 7, cut out cock No. 10 under the deck and all dampers should be closed. It is important that these precautions be observed particularly when placing engines in the roundhouse as the firing valve may be acidentally opened by workmen in the cab and if the other valves have not been closed, oil will escape through the burner and a fire may result.

DUTIES BEFORE DEPARTURE

In addition to the duties usually performed on any engine before departure, the fireman should observe the condition of draft pans and brick work, observe the condition of burner, dampers, and pipe connections between engine and tender, try the oil regulating valves; see that the burner is properly delivering fuel oil to the fire, see that the heater is in working order; and that proper supplies of fuel oil, sand and water have been provided, as well as the necessary tools for handling an oil fire. Where heavy oil is used, blow out the burner before beginning each trip.

TOOLS

The tools necessary for firing an oil-burning engine include sand horn (Fig. 15) and brick hook (Fig. 16).

FIRING

It should be remembered that the preservation of the firebox and flues is as important as keeping up steam or making time. To this end engineers and firemen should co-operate to prevent cold air from being drawn into the firebox and through the flues.

The fireman should be at the firing valve when the engine is started. He should increase his fire immediately before the throttle is opened and should reduce it immediately after the throttle is closed. Any change in the position of the throttle or reverse lever while running should be correspondingly anticipated by the fireman and the fire regulated accordingly. The fire must at all times be regulated to suit the work the engine is performing. When there is a probability of the driving wheels slipping, the firing valve should be opened sufficiently to guard against the fire being drawn out by the exhaust in case slipping occurs. At other times the fire should be regulated so as to maintain uniform steam pressure most economically.

The engineer should call the fireman's attention when about to change the position of the throttle or reverse lever.

A white incandescent color at the peep hole in the fire door and the complete absence of smoke at the stack is most desirable. Black smoke indicates incomplete combustion and waste of fuel

and should be avoided. Leaky steam pipes, superheater, flues, firebox seams, or improper combustion from any cause will produce a ruddy color in the firebox.

The firing valve and not the injector should be used to control the steam pressure. The operation of the injector should be as nearly continuous as possible while the engine is working. Variations in the water requirements of the boiler should be met by partially opening or closing the injector water valve as required. If, when the engine is working, the steam pressure approaches the popping point and the injector is shut off, the injector should be started, only if the boiler needs water. If no water is needed the fire should be reduced. If the injector is started, the firing valve should be left alone or opened slightly if necessary to maintain working pressure. In no case should the fire be reduced and the injector started at the same time in order to prevent popping.

The use of the injector when standing or drifting should be avoided as far as possible. When it is necessary to use the injector under these conditions, it should be used intermittently and a good fire should be maintained as long as the injector is in use.

Forcing the fire on an oil-burning locomotive is likely to injure the firebox sheets and flues and in the event of it being absolutely necessary to force the fire beyond a reasonable point, unusual care should be taken to see that sufficient water is on the crown sheet to prevent damage.

When standing or drifting, the dampers should be closed and a light fire maintained in order to maintain as nearly as possible a uniform temperature in the firebox to prevent injury to the firebox and flues.

ATOMIZER

Except when the fire is being lighted the atomizer jet must be strong enough to carry the oil from the burner to the flash wall.

When the engine is working, it is desirable to use as little atomizer as will produce complete combustion. An atomizer jet of execessive force will damage the flash wall by cutting away the bricks and may cause a deposit of carbon. If the atomizer jet is too weak it will cause smoke and imperfect combustion; if too strong it will produce a rapid succession of explosions commonly known as "Drumming." The proper adjustment for the atomizer lies between these two extremes.

When the engine is standing or drifting, the use of too much atomizer with the light fire usually maintained will create a disagreeable gas and cause the fire to burn with a succession of light explosions causing puffs of pungent smoke at the peep hole. Under the same conditions too little atomizer will result in incomplete combustion and the oil, not being carried far enough into the firebox, will drip from the mouth of the burner into the draft pan. If this condition is allowed to continue, the oil will run out of the draft pan to the ground where it will be likely to start a fire.

If the fire kicks and smokes, the atomizer should be readjusted. If this fails to stop the trouble, the temperature of the oil should be investigated and the heater put in use if necessary as the oil

may be too cold. Another possible cause of trouble of this nature is water in the oil. If this is found to be the source of the trouble, valve No. 9 should be opened at once and all water drained out of the oil tank.

BLACK SMOKE

Black smoke should at all times be avoided. The production of smoke is evidence of imperfect combustion and waste of fuel. The soot deposited by smoke on the heating surfaces of the boiler is a non-conductor of heat and will make an oil-burning locomotive fail in steam quickly. Unless the steaming of an oil-burning locomotive is interfered with by such defects as improper drafting, defective brick work, defective cylinder packing, or leaks in firebox, flues, steam pipes or superheater, the production of black smoke can be prevented by proper handling of the firing valve, atomizer, heater, and dampers. If it is found to be impossible to make an engine steam without smoke, the cause of the trouble should be ascertained and reported promptly in order that the necessary repairs can be made.

Particular care and attention is required to prevent black smoke when stopping or starting. This can be accomplished only by very thorough co-operation between engineers and firemen in handling the throttle and firing valve as explained under the subject of "Firing."

Live steam blowing into the oil feed pipe either through the burner blow-out valve No. 3 or through blow-back valve No. 5 will cause the engine to steam poorly with intermittent puffs of smoke. These valves must be kept closed tight when the fire is burning. Similar effects are sometimes produced when the oil is too hot or when the air vent to the oil tank is stopped up so as to prevent a steady flow of oil to the burner.

SANDING

Flues should be cleaned of soot when running, by placing a small quantity of sand in funnel, or horn, and by inserting same in the opening provided in the fire door while the engine is working hard, allowing the exhaust to draw the sand through the flues, thus cutting the soot from them in its passage and discharging it from the stack. It is better to use sand frequently and a small quantity at a time than to use large amounts only a few times on a trip. It is necessary that the flues be cleaned of soot on leaving terminals or siding where the engine has been at rest for any length of time, and also as often as found necessary to aid the engine in steaming. This depends to a great extent upon the degree of perfection with which combustion is obtained. Attention should also be given the flues just prior to entering points where engine is to be put in roundhouse or otherwise detained, in order to leave the flues clean, as this will aid getting engine under steam with little delay where the blower alone is to be relied on for draft.

The sand funnel should be held as far in the firebox as possible in order to prevent the sand from falling on the brick work or flash wall, and the funnel should be shaken to insure the sand reaching all of the flues.

Flues are not to be sanded when passing stations or other places where the sand or soot discharged from the stack might be objectionable.

Sand delivered to oil-burning locomotives for sanding flues shall be thoroughly screened and dried. Care should be used to see that there are no pebbles or other large pieces in the sand, as they will lodge in flues around superheater units and stop them up, as well as gather on floor of draft pan and obstruct the flame. More sand is needed to clean flues when using heavy oil than is the case with light oils.

EFFECT OF WATER IN OIL

Water in the oil will produce intermittent flashes or kicking of the fire in the firebox and at times the fire will die down entirely and then flash up as the water disappears and the oil reaches the burner. Water in the oil produces a very dangerous condition and should be prevented immediately by opening valve No. 9 and draining the water from the fuel oil tank.

Before leaving and arriving at terminal, and at other convenient places while on the road, valve No. 9 to oil tank drain should be opened and all water allowed to run out. It is very important that water shall not be allowed to accumulate in the oil tank, as the spasmodic fire which results will not only cause steam pressure to drop but may cause the flues to leak.

An excessive accumulation of water in the oil tank indicates a leak in the heater. When such an accumulation is observed, report the heater to be examined for leaks.

LOCATION OF EQUIPMENT

Drawing Fig. 17 shows location of the various cab valves, tank fittings and other oil-burning equipment. The numbers and direction below refer to this equipment:

No. 1. Blower valve
No. 2. Atomizer valve
No. 3. Burner blow-out valve
No. 4. Tank heater valve
No. 5. Blow-back valve
No. 6. Firing valve handle
No. 7. Firing valve
No. 8. Heater exhaust valve
No. 9. Oil tank water-drain valve
No.10. Main cut-out cock
No.11. Safety oil valve

To use blower, open valve No. 1
To deliver steam to atomizer, open valve No. 2.
To deliver steam to heater, open valve No. 4.
To drain water out of oil tank, open valve No. 9.
To blow out burner, close firing valve No. 7, and open valve No. 3.

In case of failure of the heater pipe, the oil can be heated through the feed pipe by opening valve No. 5. After heating the oil in

this manner, be sure valve No. 5 is closed tightly. Unless this is done, oil will not flow regularly and engine will not steam.

Should valve No. 11 become disconnected, it can be unseated by screwing up the emergency set screw at the bottom of the valve casting underneath the oil tank.

The cotter key in the oil safety valve rod must be applied from the front in order that it can be pulled out quickly by jerking the emergency cable. Proper application of this key is shown by the accompanying diagram.

INSPECTION AND MAINTENANCE

Before application to a locomotive, each oil burner is to be carefully inspected and tested. The atomizer port must be free from obstructions, such as fins, chips, loose scales, etc. This port must be of exactly uniform width throughout its entire length. If it is wider at one side of the burner than at the other, more oil will be drawn from that side with the result that the fire will be directed to one side of the firebox and may not entirely fill it. The upper and lower lips of the atomizer port must be even. A slight extension of one beyond the other will direct the flame upward or downward. Each burner should be tested with steam before it is placed on an engine to make sure that the atomizer jet has the proper shape and force to do the work required of it.

There must be no sand holes or other openings in the partition wall between the steam and oil passages through the burner. Openings through this wall will cause an irregular flow of oil through the burner. Each burner should be carefully examined for these defects before being applied.

The burner should be applied so that the atomizer jet will be parallel with the floor of the draft pan, and approximately central between the sides of the pan. The locomotive folio shows the method to be followed in lining up locomotive oil burners.

Oil-burning locomotives on arrival at terminal should have all parts of the oil-burning equipment carefully inspected, and if repairs are needed, they should be made promptly. The burner should be examined to make sure that it is in good working order and in proper position and alignment. All pipes, valves, flexible joints, etc., should be examined for leaks, loose clamps, etc. The draft pan and its supports should be carfully examined to see that they are in good condition and that no part of them comes in contact with the frames, spring rigging, or machinery. The draft pan should also be inspected for air leaks, particularly around the mud ring. The dampers should be examined and tried, to see that they work properly. As soon as the engine has cooled off sufficiently, the inspector should enter the firebox and examine the brick work to make sure that it is in suitable condition for service and that there is no likelihood of any bricks working out of place or falling down into the bottom of the pan.

The firebox and flues should be inspected for leaks and the flues are to be tested with a torch to see that they are not stopped up. The flame of the torch is to be applied to the firebox end of each flue. If the flue is open, the draft will suck the flame into the flue. Flues must be maintained in clean condition and engines must not

be allowed to go out with flues stopped up. This rule applies to superheater flues as well as to the smaller flues.

When small flues are stopped up they are to be bored out with augers of sufficient length to reach from end to end of the flue. After being bored the flues are to be thoroughly blown out with air.

Superheater flues are to be cleaned and blown out as described by the locomotive folio. It is important that superheater flues be kept free from deposits of sand or other obstructions.

Flue boring must be done before flue leaks are repaired.

After flues have been bored and blown out they are to be inspected and Ok'd by a competent boiler inspector or other authorized person before the engine is fired up.

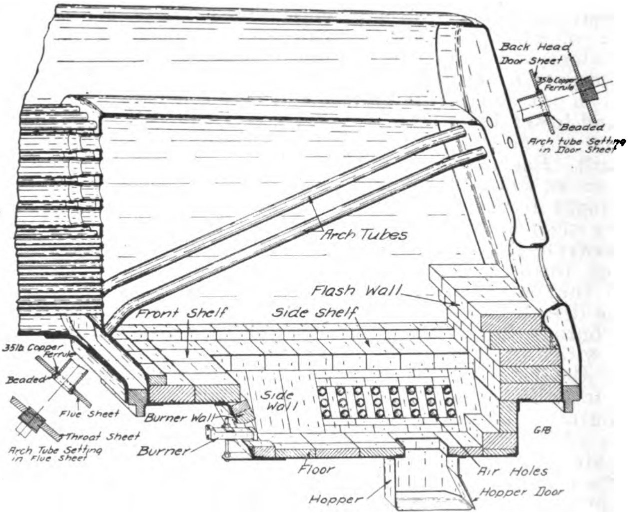


FIG. 18.

Arrangement of Brick Work Oil-Burning Firebox

Accumulations of carbon, sand, or other foreign material should be removed from the draft pan after each trip. In case of excessive deposits of carbon the cause of the trouble should be ascertained and the proper remedy applied.

ENTERING OIL TANKS

Before being entered by workmen, oil tanks must first be steamed out thoroughly and then washed out with cold water, to insure the removal from tanks of any gas that may have accumulated. Employes are positively prohibited from entering tanks

which have contained crude oil until above instructions have been complied with, and they shall keep lanterns, torches or any other open light out of oil tanks. When necessary to have artificial light in an oil tank, use nothing but electric or incandescent light.

APPLYING BRICK WORK

Brick work in oil-burning locomotives is to be applied and maintained in accordance with the brick work folio.

In applying brick work, spaces between bricks and around air tubes, etc., are to be filled with a mixture of fire clay and fine sand. This mixture is to be composed of two parts of clay to one of sand, and is to be stirred in with water to the consistency of a thin paste. The mixture applied between the bricks should be thin and the bricks placed as close together as possible. Large quantities of the fire clay mixture should not be used at any one point or depended upon entirely as a fire resisting surface. After the brick setting has been completed all exposed surfaces are to be coated with a solution of soda ash and water mixed until it will flow freely. This makes a very satisfactory glaze over the bricks and provides a good fire resisting surface.

Under no circumstances shall brick work be cooled by pouring water over it.

HOLLOW STAYBOLTS

Staybolts behind all brick work shall be hollow. As engines in coal-burning services are changed to oil-burning service, hollow staybolts are to be applied back of brick work when the oil-burning equipment is applied.

A hollow staybolt shall have a 3-16" hole throughout its full length, the hole being located centrally.

EXTINGUISHING OIL FIRES

All roundhouses in which oil-burning locomotives are handled are to be provided with strong barrels of about 50-gallons capacity for storing sand to be used for extinguishing oil fires. One barrel is to be located between every alternate pair of pits. These barrels should be kept filled with sand, and shall be inspected periodically to see that they are full and that the sand is dry. The sand is not to be used for any purpose other than extingushing oil fires. An old or scrap scoop is to be kept in top of barrel.

These barrels are to be painted red, and stenciled with black letters 2" in height: "SAND FOR OIL FIRE ONLY." Similar fire-extinguishing equipment must be maintained at inspection pits and oil supply stand pipes.

In case of oil which has dripped in pit or elsewhere catching on fire, throw sand on it promptly. Sand will put out an oil fire when water will not.

If oil is escaping from the draft pan or from broken or leaky pipes under the engine or tender, the safety oil valve No. 11 in the tender oil tank should be closed by pulling the emergency cable.

If access to this valve is prevented by fire, the cut-out cock under the tender deck should be closed. This can be done from a safe distance by means of a clinker or carbon hook applied to the handle or loop in the operating rod connected with this cock. The end of this operating rod will be found near or between the gangway steps on the left side of the tender. The cut-out cock is closed when the operating handle is pulled out.

GENERAL

Leaks. Leaks in tanks or oil connections must be corrected at once.

Vent. Care should be taken to know that the vent to the fuel oil tank is open.

Lost Motion. Excessive lost motion between engine and tender should not be permitted to exist, as it will tend to loosen or break pipe connections.

Safety Oil Valve. The safety oil valve on the tank and the wire cable to the cab must be kept in good order and be operative at all times.

Fire. In case of accidental fire when standing, or in case of derailment or accident when running—the hoslter, fire-builder, engineer or fireman, or whoever is on engine, must pull the safety cord immediately and be positive that the safety valve is closed.

Atomizer and Damper. The same adjustment of atomizers and dampers will not apply to all engines. A slight change will often produce better results.

Carbon. The bottom of draft pan should be inspected to see that pieces of brick and carbon do not obstruct the oil spray from the burner.

Heater. Do not put on the heater and forget all about it until the oil in the tank boils over.

Sanding. Flues should be sanded frequently. The best practice is to use a small quantity at a time.

Fireman. The fireman should not wait for the engineer to instruct him to shut off the oil supply. It is his duty to watch and to be governed by the engineer's movements of the reverse lever and throttle.

Blower. The blower should be used with judgement. Open it sufficient to create the necessary draft when the throttle is closed. Too much opening is hard on the flues and sheets.

Drain Water. Drain the water out of the oil tank frequently.

Brick Work. Examine the brick work at the end of every trip.

Firing. Care should be taken to maintain an even temperature in the firebox. It should not be increased too rapidly by forcing the fire or reduced suddenly by permitting cold air to pass through the firebox and flues. It is of the utmost importance that this even temperature be maintained to preserve the life of the firebox and flues, and to prevent engine failures by leakage of same.

Wasting Fuel. In view of the ease with which an extravagant waste of fuel can be effected in burning oil, it is especially urged that every effort be exerted to properly handle the engine and the burner and its accessories, in order to obtain economical combustion and to guard against injury to the boiler or firebox.

DEFINITIONS OF TERMS

Atomizer. That portion of the burner which delivers steam used for carrying and breaking up oil into small particles to aid combustion.

Black Smoke. Soot from partially consumed oil. A sign of poor combustion and poor firing.

Brick Work. Fire brick used in lining the firebox and draft pan to protect the mud ring, firebox, draft pan and fire door.

Burner. A device for atomizing and delivering oil to the firebox.

Carbon. A grayish black element forming on the floor of the draft pan or firebox of an oil-burning locomotive. Generally formed by some foreign object, such as a broken brick, tool, or bunch of waste being left on the floor of the draft pan near the burner.

Damper. A metal slide or lid used over the air openings of the draft pan to regulate the amount of air admitted to the firebox.

Fire Door. An opening in the back head of a locomotive boiler through which workmen may enter the firebox for inspection and making repairs. It should be kept closed while engine is on the road or under fire.

Firing Valve. A device for regulating the flow of oil to the burner.

Flash Wall. An arrangement of fire brick in draft pan towards which the fuel oil is delivered and which assists in vaporizing and igniting the oil. Also directs the course of the flame.

Heater. A coil of pipe in the oil tank through which steam passes to heat the oil.

Manhole. The covered opening to the oil tank on the tender.

Measuring Rod. A steel rod for measuring the amount of fuel in the oil tank.

Oil Burner. A locomotive using oil for fuel instead of coal.

Oil Safety Valve. A device in the oil tank for immediately shutting off the flow of oil to the burner.

Peep Hole. A small circular hole in the fire door sometimes called sand hole.

Sand Horn or Funnel. A device used in delivering sand to the peep or sand hole in the fire door for cutting soot and gum from the flues, flue sheets, and side sheets.

Soot. A black carbon forming on flues, flue sheets, and side sheets, due to unconsumed oil. It is evidence of poor combustion.

STEAM

The so-called vapor seen escaping from a vessel of boiling water, or rolling in clouds from the exhaust of an engine is composed of very minute drops of water. It is one of the physical manifestations of steam resolving itself back to water through the process of condensation. The change which is visible is caused by the contact of the steam with cold air.

As the water in a boiler is transformed into steam it rises into the steam dome and from there it is released by opening the throttle valve and is then conveyed through the dry pipe and steam pipes to the steam chests and from there to the cylinders. The expansive power of the steam exerted on the pistons in the cylinders is the basis of the propelling power of the locomotive.

Saturated steam is steam either in contact with the water from which it was generated, or if separated therefrom is kept at the same temperature and pressure. Wet steam is steam not only saturated but also holding in suspense unevaporated water in the form of minute drops; it holds this water in suspense mechanically, due either to such causes as ebulition or rapid boiling of the water from which it is generated, or from a rapid flow of steam from near the surface of the water, or from partial condensation.

Dry steam is the term usually used for saturated steam that is free from suspended water. It is used in distinction from wet steam. Superheated steam is steam removed from contact with water, and heated above the temperature of the water from which it was generated. Steam more closely resembles a perfect gas when superheated than in any other state.

EXHAUST NOZZLE AND DRAFT

The steam, after it has been admitted to the cylinders, is used for another useful purpose. After it has performed its work in the cylinders of the locomotive it is exhausted through the nozzle tip and smoke stack to create the necessary draft for the proper combustion of the fuel placed in the firebox.

The nozzle tip is so constructed that the steam passes out much in the same manner as a stream of water through a hose nozzle, the column of steam being allowed to expand sufficiently so that it touches the inside edges of the smoke stack on its way out. If it is desired to increase the velocity of the steam passing through the nozzle tip, it is necessary to increase the pressure forcing it through the tip. Usually this is done by reducing the size of the opening so that the desired increase in pressure will be obtained. In this manner air is driven out of the smoke stack which causes air in the smoke box to also be drawn out with the steam. This creates a circulation of air through the flues and firebox, and when the fire door is closed, circulation is also established through the grates and ash pan. The steam generated in the boiler, therefore, is used not only to propel the locomotive, but also to provide the draft necessary for the proper burning of the fuel placed in the firebox.

It is sometimes found that due to the height of the nozzle tip above the cylinder saddles, or bottom of the smoke arch, that the steam does not spread out sufficiently to properly fill the smoke stack through its entire circumference, in which case it is necessary to cause the steam to spread out earlier after leaving the nozzle tip. In order to accomplish this, what is called a split or bridge is placed across the nozzle opening, as shown in Fig. 1, No. 231, about one inch above the nozzle tip. The bridge or split is flattened so that its sharp edges will spread the steam leaving the nozzle tip and cause it to spread out much in the same manner as would be the case if a knife blade was placed directly across the center of a hose nozzle to spread the water. The two ends of the split are bent down so that they might be fastened to the outside of the exhaust tip to hold the split or bridge in place.

It is obvious that under like conditions of pressure, etc., a large opening will permit a given volume of steam to escape in a shorter time than will a smaller opening, therefore the nozzle tip should be as large as possible and still impart to the exhaust jet sufficient velocity to properly drive the gases out of the smoke stack and flues, producing the necessary circulation through the flues and firebox for proper steaming. Reducing the nozzle opening restricts the flow of steam from the cylinders to the atmosphere in proportion, and if reduced sufficiently the results will be practically the same as when the engine is improperly handled by working the valves at long cut-offs under high speeds.

In order that there might be a free flow of air through the ash pan, grates, flues and smoke box, the nozzle tip must be maintained in its proper relation to the smoke stack. On certain classes of engines a sleeve or petticoat pipe is interposed between the nozzle tip and the base of the smoke stack in order to properly direct the steam into the stack, and provide for operating with a larger opening in the exhaust tip. In other words, the nozzle tip sometimes sets so far below the base of the stack that the steam would spread out so that it would more than fill the smoke stack, in which case some of the steam would strike beyond the inside of the stack and be driven back down into the smoke box, thus tending to drive the air in the smoke box back through the flues toward the firebox, instead of drawing it out through the stack.

When the petticoat pipe is applied the steam expands into the petticoat pipe and is carried through it close to the base of the stack and is then allowed to expand out into the stack. It can be seen from this that the petticoat pipe must also set centrally under the stack and over the nozzle tip. If it should not be set parallel with the nozzle tip and smoke stack, the steam would be directed to one side of the stack which would reduce the amount of air forced out of the stack and consequently reduce the circulation throughout the flues and firebox. If the petticoat pipe was located out of center with the nozzle tip and smoke stack, the results would be the same. It is essential that the nozzle be located exactly central with the center of the smokestack.

ACTION OF STEAM

In steam, as in other gases, there is a natural repulsion between the various particles, each particle trying to separate itself from the others so that it will fill the receptacle in which it is confined. Its natural tendency is to expand and thus push out whatever is resisting it. If the steam is enclosed and superheated, the natural tendency of its particles to separate is intensified and we thus obtain increased work from a given weight than is possible with saturated steam.

If we should take an open kettle filled with water setting on a fire, and allow all the water to be evaporated without creating any pressure, there would be little or no noise created during the time the steam was passing to the atmosphere. However, if a small opening was provided so that the steam would be generated faster than it could escape from the kettle a pressure of steam would be accumulated inside the kettle which would cause a considerable noise as it was passing out through the restricted opening. Increasing the pressure would increase the noise made by the flowing steam and decreasing the pressure would decrease the noise in proportion. Therefore the sound created by the exhausting of steam into the atmosphere is due more to the pressure of the steam than to its volume.

It can be seen from this that when the exhausts at the smoke stack of a locomotive are loud and heavy, that steam under a heavy pressure is being passed through the nozzle tip. We know that steam under a heavy pressure has power to do considerable work, and unless it is permitted to escape from the cylinder after it has done its work, it will resist the return movement of the piston by offering what might be termed back pressure, or a pressure in the cylinder on the exhaust side of the piston, which prevents the live steam on the opposite side from freely moving the piston throughout its stroke.

When the exhausts from the nozzle are sharp and there is an interval between the exhausts when no sound is produced, it is evident that the pressure in the exhaust side of the cylinder is very low. On the other hand, if the steam is being discharged at the nozzle tip so rapidly and in such quantities that the exhausts are very loud and there is no interval which will enable the exhausts to be readily distinguished, the steam which is being exhausted is still capable of doing considerably more work through its expansive power and also there remains in the cylinder a considerable pressure which is tending to obstruct the return movement of the piston. Such a condition is brought about by so working the engine that the steam from the boiler is allowed to follow the piston almost its entire stroke, until the speed has been increased to such an extent that the flow of steam through the exhaust channels in the saddles to the nozzle tip is practically continuous. Under these conditions the live steam from the boiler is retarded in its work of moving the piston by the pressure thus maintained on the exhaust side of the piston. This reduces the power that it is possible for the engine to develop and the speed that it might attain.

Shortening the cut-off, by moving the reverse lever toward the center allows the boiler pressure to follow the piston through only

a portion of its stroke and permits the steam to complete the piston's movement under its expansive power, at the same time causing its pressure to be reduced by the time the valve opens the exhaust port, when a further reduction in pressure takes place. The results then would be the same as carrying an increased boiler pressure, because the pressure on the exhaust side of the piston would be considerably reduced, giving more power to the live steam on the opposite side of the piston, permitting it to force the piston more freely throughout its stroke. It would be possible to distinguish each exhaust as it occurred, by providing an interval during which there was little or no pressure remaining in the cylinder, and it would be possible to obtain greater power and speed with the same amount of steam or maintain the same power and speed with a greatly reduced expenditure of coal and water.

The natural tendency is for steam under pressure to expand or push out in all directions. If, therefore, steam is admitted to a locomotive cylinder at 100 pounds pressure and is caused to follow the piston at this pressure for its full stroke, the average cylinder pressure would be 100 pounds.

If steam at 150 pounds pressure is admitted to the cylinder and allowed to follow the piston at this pressure for only a short distance, and is then cut off by the valve closing the steam port, the confined steam in the cylinder will continue to push on the piston after the supply from the boiler is cut off. In this case the withdrawal of steam from the boiler only lasts until the valve closes the admission port, after which the steam begins to expand.

If the steam, which was admitted at 150 pounds pressure for only a portion of the stroke, had reduced to 50 pounds pressure when the valve opened the exhaust port after the steam had completed the movement of the piston, then the average pressure would be 100 pounds as in the former case. A smaller volume of steam at a higher pressure would have therefore given the same average cylinder pressure, and the pressure being lower when the exhaust took place would insure a lower pressure on the exhaust side of the piston during its return stroke.

SHORT CUT-OFF AND FULL THROTTLE

The results to be obtained by allowing the steam at boiler pressure to follow the piston for only a short distance and then complete the stroke under the expansive force of the steam, or of allowing steam pressure lower than boiler pressure to follow the piston for a much greater distance is shown in the following example taken from ordinary service during various tests:

3,160 Class (As Shown in Fig. 1.)

Speed miles per hour	Indicated horse power	Throttle position	Cut-off per-cent	Pounds of water per hour
20	1775	Full	35	40,100
20	1605	Partial	65	48,800

The above example demonstrates that the steam chest pressure should be maintained as high as possible at all times, in order to accomplish this the steam should be cut off from the cylinders as early in the stroke as the conditions will permit, and the throttle should be opened wide enough so that the steam will have free access from the boiler to the steam chest. If the throttle is only partly opened the pressure will be much less in the steam chest than is possible to obtain with the throttle opened wide. In the tests from which the above example was taken, an engine such as is shown in Fig. 1, would use 5,858 gallons of water per hour under a long cut off and light throttle, while with a short cut off and full throttle the water consumption would be 4,813 gallons, or a difference of 1,045 gallons in favor of the short cut off and full throttle.

CONDENSATION OF STEAM

When steam comes into contact with surfaces of a temperature lower than the temperature of the steam, condensation takes place. If, therefore, an engine has been standing for a considerable period the various pipes and channels throughout the cylinder saddles, also the steam chests and cylinders may be at the normal temperature of the atmosphere or near that temperature, so that when steam is passed from the boiler to the steam chests some of the steam is condensed when it first enters these parts. A certain amount of condensation continues to take place until the cylinder saddles, steam chests and cylinders are heated up close to the temperature of the steam passing through them. It takes some little time to bring this about, that is, an engine will have to be operated for some considerable distance before all the parts which the steam comes into contact with have been heated up to as near the steam temperature as possible.

Dry steam under pressure is flexible, that is, if permitted to do so it will expand and fill a much larger space than that in which it is confined. In doing this the steam pressure will diminish as expansion takes place. Steam may also be compressed into a smaller space which will cause the pressure to rise.

When a reduction of pressure occurs, as stated above, the temperature of the steam falls at the same time, and if steam is allowed to expand until there is no pressure remaining, the temperature of the steam will be reduced to the point at which water boils in an open vessel, or 212 degrees F. The steam at this time would revert to water. On the other hand, if steam heavily saturated with water was compressed into a smaller space, the steam not being as flexible as when dry, could not be compressed to the same degree. Water itself is practically inelastic, therefore, when compressed its pressure rises very rapidly. If the piston was nearing the end of its stroke and the space between the piston and cylinder head was filled with water, a very slight movement of the piston would increase the water pressure enormously. For example: An engine as shown in Fig. 1 having cylinders 27 x 32 inches with 63 inch drivers, would at a very low speed develop the following stresses on cylinder heads and cylinder castings:

Stresses common to locomotives as shown in Fig. 1, if cylinders are not drained of water:

Distance of piston from end of stroke, in.	Total steam pressure, lb.	Water pressure on cylinder head			
		Total pounds		Pounds per sq. in.	
		Normal rail	Sand	Normal rail	Sand
4	106,610	244,500	341,000	553	769
2	106,610	412,000	566,000	720	989
1	106,610	627,000	851,500	1095	1487
½	106,610	922,500	1,249,000	1610	2180

DRAINING CYLINDER AND VALVE CHAMBERS OF CONDENSATION

In order to provide for the removal of any accumulation of water in locomotive cylinders, holes are drilled in the bottom of the cylinder at each end, into which drain valves or cylinder cocks are applied and so arranged that they may be opened or closed by the engineer from the cab. It is important therefore, that when there is a possibility of water entering the cylinder, that the cylinder cocks shall be opened and left open until the temperature of the cylinders and other parts connected thereto is such that the condensation of steam is reduced sufficiently so that the amount of water condensed will not be in such quantities as to completely fill the clearance space in the cylinder.

DAMAGE DUE TO CONDENSATION

The cylinder and all its parts, as well as all connections leading thereto are designed to withstand considerably more than the steam pressure ordinarily carried in the boiler. However, if water accumulates in the cylinder and is not allowed to escape through the cylinder cocks it must be forced out through the steam ports with the exhaust. If, when the piston is forcing water ahead of it out through the exhaust port, the valve should close as the piston nears the end of its stroke, there would be no further means of escape for the water remaining in the cylinder. The crank pin at this time may be pushing upon the piston after the steam pressure has forced the piston the greater part of its stroke, the crank pin at this time would be near the center and the momentum of the engine would tend to carry the crank pin by the center. Under these conditions enormous pressure would be created between the piston and cylinder head and also throughout the port leading to the valve chamber or steam chest. Heavy stresses would also be set up in the piston rod, the cross head and wrist pin, also the main rod and the main crank pin, in addition to the strains set up in the wheel, axle, driving box and frames.

The result of these strains is conducive to broken axles, driving wheel spokes, crank pins, bent or broken main rods, wrist pins, cross heads as well as loose guides, bent or broken piston rods, broken piston heads, cylinder and piston rod packing, cracked cylinder heads, or broken cylinder castings and broken main frames. This pressure is all out of proportion to that which can be obtained through the ordinary working of the engine under its full power, and since condensation is greatest when the cylinders, steam chests, saddles and their connections are cold, such as would be the case if the engine had stood for a considerable time, it is very essential that before starting an engine from a state of rest, cylinder cocks and channel cocks must be opened to allow condensation to escape from cylinders and valve chambers.

THE CYLINDER COCKS SHOULD BE OPEN WHILE THE ENGINE IS STANDING, IN ORDER THAT ANY CONDENSATION TAKING PLACE IN THE CYLINDERS MIGHT NOT ACCUMULATE.

THE CYLINDER COCKS MUST BE OPENED BEFORE OPENING THE THROTTLE TO ADMIT STEAM TO THE CYLINDERS WHEN STARTING AN ENGINE FROM A STATE OF REST. IF THE ENGINE HAS STOOD FOR SOME TIME, ALLOW SUFFICIENT TIME FOR THE WATER TO BE BLOWN FROM THE CYLINDERS AFTER OPENING THE THROTTLE AND UNTIL THE STEAM SHOWING AT THE CYLINDER COCKS IS COMPARATIVELY FREE FROM WATER. THE ENGINE SHOULD THEN BE MOVED SLOWLY FOR A FEW REVOLUTIONS AND NO ATTEMPT SHOULD BE MADE TO HURRY THE MOVEMENT OF THE ENGINE, BECAUSE UNDER THESE CONDITIONS SLIPPING OF THE DRIVERS IS LIABLE TO OCCUR, IN WHICH CASE THE PISTON SPEED MAY BE SO HIGH THAT WATER IN THE CYLINDERS IS UNABLE TO ESCAPE THROUGH THE CYLINDER COCKS, OR EXHAUST PASSAGES, AND A SUFFICIENT AMOUNT WILL BE TRAPPED IN THE END OF THE CYLINDER WHEN THE VALVE CLOSES THE PORT TO ENTIRELY FILL THE CLEARANCE SPACE, CAUSING A VERY HEAVY PRESSURE IN THE CYLINDER. UNDER THESE CONDITIONS VERY DAMAGING STRAINS ARE PRODUCED AND CYLINDER CASTINGS AND OTHER PARTS MAY SUSTAIN INVISIBLE CRACKS AND LATER ON FAIL IN ORDINARY SERVICE. EVEN AFTER THE ENGINE HAS BEEN MOVED OUT OF THE ROUNDHOUSE TO THE OUTGOING TRACK, THE ENGINEER SHOULD REMEMBER THAT THE CYLINDERS AND THEIR CONNECTIONS ARE STILL COLD ENOUGH TO PRODUCE CONSIDERABLE CONDENSATION, HE SHOULD THEREFORE MOVE THE ENGINE SLOWLY WITH CYLINDERS COCKS OPEN WHEN STARTING, AND ABOVE ALL AVOID SLIPPING THE ENGINE AT THAT TIME.

VALVE GEAR

The term valve gear or valve motion refers to a system of eccentrics, eccentric rods and levers that transmit motion to the main valve which admits steam to, and exhausts it from, the cylinders of an engine. The principal parts are the eccentrics, the eccentric rods, the reversing link, the rocker arms and valve rods, the link hangers, reverse shaft arms, reversing shaft, reach rod and reverse lever.

The Stephenson valve gear is located between the frames, as shown in Fig. 19, and consists of four eccentrics fastened to the driving axle and which revolve with the axle. The eccentrics are merely discs fastened rigidly to the driving axle. The hole through the eccentric which receives the axle, being bored out of center sufficiently so that as the axle revolves the eccentric will produce a back and forth motion similar to a crank. This motion is transferred to the eccentric rod 2, which is fastened to the eccentric strap 3, which surrounds the eccentric 4. The eccentric rods fasten also to the links 1, one eccentric rod fastening to the top of each link, and the other to the bottom. The motion of the eccentric rods is therefore transferred to the links. Inside the slot in the link is fastened a sliding link block 7, which is attached to a rocker arm 8, the motion of the link block is therefore transferred to the valve rod 11 through the rocker shaft 9 and the arm 10 to the valve 12.

Assuming that the reverse lever is moved to the forward position in its quadrant, this moves the reach rod 26 and the reverse shaft 24, carrying with it the reverse shaft arm 23, and link hanger 6. As the link hanger 6 is attached to the center of the link, it causes the link to be moved downward so that the link block will be in line with the eccentric rod connection at the top of the link. The eccentric rod in this case being connected to the eccentric which is adjusted in its relation to the crank pin, as to cause the engine to run forward.

If the reverse lever is moved to the backward position in its quadrant, the link will be raised so that the link block will be in the bottom of the link and almost directly opposite the eccentric rod which is connected to the other eccentric. This eccentric being so set in relation to the crank pin as to cause the engine to run backward.

A locomotive has two engines, one for each side. It has also two eccentrics for each side, both eccentrics being connected to the link and valve rod as described above. In order that it will be possible to cause the engine to start at any time the driving wheels are fastened rigidly to the driving axles in such a position that when the crank pin on the right is on the forward dead center, which is on a horizontal line drawn through the cylinders and center of the driving axle. The crank pin on the opposite side will be on the top quarter, or one quarter of a turn behind the crank pin on the right side which is on its dead center. Referring to Fig. 19, supposing the crank pin on the left side to be in its upper position, or what is designated as the top quarter, and that the reverse lever be placed in its forward position, the movement of the link in this case would cause the valve to move to a position

to admit steam through steam passage 14, behind the piston in the cylinder to force the piston forward.

The piston 18 being rigidly connected to the crosshead 33, by its piston rod 19, moves the crosshead forward with it. Since the main rod 20 connects the crosshead to the main crank pin 34, the crank pin is also moved forward, causing the driving wheel to revolve. As the driving wheel revolves, it causes the axle to revolve, carrying with it the eccentrics 4. The movement of the eccentrics now being transmitted to the eccentric rods, links, valve rod and the main valve in the steam chest. As the main crank pin passes its front central position, the main valve reaches a position to exhaust to the atmosphere, the steam which has been used to move the piston forward, at the same time admits steam from the steam chest to the cylinder in front of the piston, causing the piston to be pushed backward in its cylinder which, of course, transmits this motion through the piston rod, crosshead and main rod to the crank pin, which is thus forced by its lower-most or bottom quarter position to its back center. At this point the valve assumes a position to exhaust to the stack the steam used to force the piston backward and again admits steam behind the piston.

If the reverse lever should be placed in its backward position, the operations described above would be reversed. It can be seen from the above description that while one crank pin is on its dead center, (in which case, of course, the piston and crosshead would be unable to move it either backward or forward, on account of the main rod being on a straight line through the cylinders and driving axle) the crank pin on the opposite side is on either its top or bottom quarter so that the full power of the piston in its cylinder is exerted to either pull or push on the crank pin, causing the driving wheel to revolve, and since the driving wheels are rigidly attached to the axles, the crank pin on the opposite side would be moved away from its central position toward its top or bottom quarter.

When the main valve moves in its steam chest in the same direction as the eccentric rod which is controlling it, the valve motion is designated as direct motion, however, when any system of rocker arms or a combination of levers is introduced, which causes the valve to move in a direction opposite to that of the eccentric rod which is controlling it, it is designated as indirect motion.

VALVE LEAD

When the crank pin is on its forward center, the position of the two eccentrics are such that the link stands in a vertical position, however, the slot in the link is not straight but curved equal to a radius from the center line of the main axle to the center line of the link slot, therefore, if the reverse lever is placed in its forward position, the link block is caused to move in proportion to the swing of the eccentric rods. At this time, however, the valve is moved to a position that will slightly open the steam port from the steam chest to the front end of the cylinder. The amount of opening given to the steam port by the valve at this time is designated as lead opening, and may be described as the amount

the steam port is opened when the piston is at its dead center or at the beginning of its stroke. The lead opening given a valve is for the purpose of insuring that the pressure in the cylinder will be equal to the pressure in the steam chest when the piston starts to move.

As the reverse lever is moved toward its central position, the link block traveling in the curved slot of the link, moves the valve slightly so that the steam port is opened a greater distance, thus it can be seen that a greater amount of lead opening is had when the reverse lever is near its central position than is the case when in its full forward or backward position. If, therefore, the reverse lever is placed in its central position in the quadrant while the engine is moving, the valve will be moved to open the port at each end of the cylinder when the piston reaches the end of its stroke. The opening to the cylinder at this time, however, will only equal the lead opening so that steam will be admitted to the cylinder through a very small port opening, and will follow the piston for only a very short distance before the valve closes the admission port.

If, however, the eccentric is so adjusted that the steam port is entirely closed and the valve must travel slightly after the crank pin moves from its dead center before any opening is had from the steam chest to the front of the cylinder, the valve is said to be set blind. If the valve is so set that its admission edge is in line with the admission edge of the steam port so that the slightest movement causes the port to open, the valve is said to be set line and line.

Fig. 20 illustrates the position of the main valve with the reverse lever in full gear and on center. The circle "C" represents the path of the eccentrics around the axle, "D" is the crank pin, "E" is the eccentric rods, "G" the link, "I" the rocker arm, "J" the valve rod and "K" the main valve. "L" is the steam ports leading to the cylinder and "M" the exhaust port leading to the exhaust nozzle. When the link is in the position shown by the dotted lines and indicated by "H", it will be noted that the eccentric rod "E" has moved to the position marked "F", and that the end of the rod at the link connection has moved back slightly on account of it being fastened at the eccentric and the opposite end traveling in a circle. This movement carries the link to this position and with it the rocker arm, and moving the valve forward to reduce the port opening. The distance "A" shows the port opening when the reverse lever is in full forward motion and the distance "B" shows the port opening when the reverse lever is moved to the center of its quadrant.

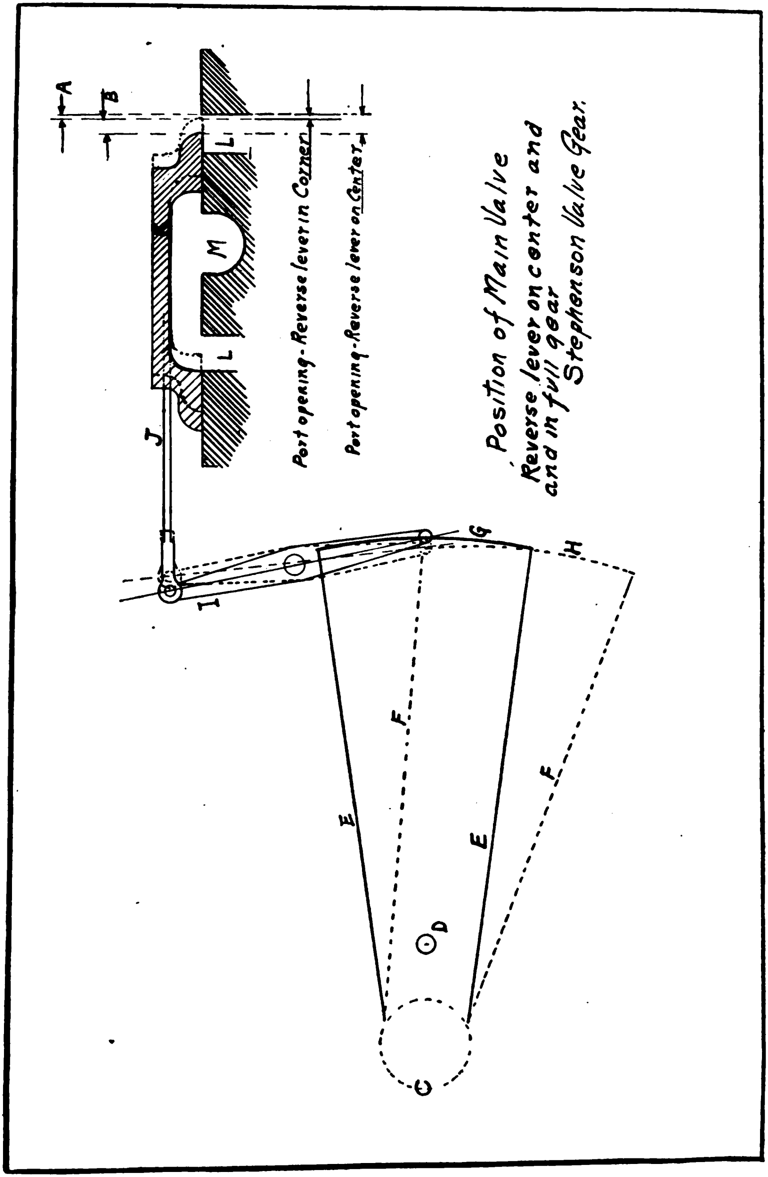

Position of Main Valve
Reverse lever on center and and in full gear
Stephenson Valve Gear.
Port opening - Reverse lever in Corner
Port opening - Reverse lever on Center
A
B
L
M
L
J
G
H
I
F
F
E
E
D
C

FIG. 20.

LEAD ADJUSTMENT

The amount of lead opening given the valve may be increased or decreased by moving the eccentrics upon the axle. Changing the lead opening by changing the length of the eccentric blades or valve rods will cause the lead to be changed unequally, that is, what is added on at one end will be taken off at the other, and vice-versa. Ordinarily, the eccentric rods are bolted to the eccentric straps with bolts having a neat fit both in the eccentric strap and the eccentric rod holes. Therefore, the eccentric rods in this case are not adjustable by simply loosening the bolts.

In some cases the center hole in the eccentric strap is oblong to permit of the eccentric rod being adjusted to the proper length when setting the valves. After this length is found the balance of the eccentric rod bolts are fitted tightly.

STEAM DISTRIBUTION

If the piston is at the front end of the cylinder, on account of the crank pin being on its dead center, and the reverse lever is placed in either its full forward or backward position, the main valve would be moved to a position to open the steam port to the amount of lead given the valve, to admit steam to the front end of the cylinder, in accordance with the manner in which the valve gear was adjusted. Steam would, therefore, be admitted into the cylinder to cause the piston to move to the back end of the cylinder. As the piston moves from the end of its stroke the main valve would be moved to open its port until the maximum port opening is obtained, or until the steam port is wide open. The motion of the valve would then be reversed, and the valve would start to close the port leading to the cylinder. Under the above conditions steam from the valve chamber would be allowed to follow the piston from the beginning of its stroke until it has traveled about three-quarters of its full stroke, at which time the port would be closed. The steam would then expand until the valve has moved far enough to open the exhaust port, when the steam would be exhausted from the cylinder to the atmosphere. As the piston completes its stroke and reaches the back end of its cylinder, the valve would have moved to a position to open the steam port equal to the amount of lead given the valve for that end of the cylinder, when the piston would be forced to the front end of the cylinder, the valve opening and closing the ports in the same manner as before.

It will be noted from the above description that as the piston travels away from the cylinder head at either end, the valve is caused to open the steam port wider than is the case when the piston is at the extreme end of its stroke. Therefore, when the crank pin reaches a position about mid-way between its forward or back dead center, and the piston is near the center of its cylinder, the maximum steam port opening to the cylinder is obtained. Therefore, if the crank pin is near its bottom quarter position and the reverse lever is placed in full forward gear, the valve would be moved to a

position to open the steam port wide at the front end of the cylinder. Moving the reverse lever to the full backward position in its quadrant would cause the steam port leading to the back end of the cylinder to be opened wide, admitting steam to the back end of the cylinder, or if the reverse lever was moved to the central position in its quadrant, the valve would be moved to its mid-travel or central position on its seat, and no steam would be admitted to either end of the cylinder.

VALVE LAP AND CLEARANCE

When the main valve is placed on the center of its seat, its outside or admission edges overlap the outside edges of the admission ports to both ends of the cylinder. The amount that the admission edges of the valve overlap the admission edges of the steam ports is called the valve lap, see Fig. 23. At the same time the exhaust edges of the valve which control the exhaust pressure from the cylinder to the atmosphere may overlap the exhaust edges of the steam ports leading to the cylinders, in which case the amount they overlap the steam ports would be called the exhaust lap of the valve. If, however, the valve was so constructed that the exhaust edges of the valve were directly in line with the exhaust edges of the steam ports leading to the cylinders, the valve would be line and line on its exhaust side. On the other hand, if the valve construction was such that the exhaust edges of the valve failed to close the exhaust edges of the steam ports, the valve would be designated as having exhaust clearance.

The cylinder is also described as having clearance. This, however, is known as the space between the piston and cylinder head when the piston is at the end of its stroke and also includes the steam ports between the cylinder and the lower face of the valve. Cylinder clearance should, therefore, not be confused with clearance in the main valve.

CYLINDER COMPRESSION

When the exhaust port is closed before the piston reaches the end of its stroke the steam left in the cylinder fills the clearance space, any movement of the piston towards the end of its cylinder will then compress the steam in the clearance space. Provision is made so that compression will take place in order that the pressure in the cylinder will be nearly equal to the steam chest pressure, when the valve opens to admit steam. The compression also serves to cushion the reciprocating parts as they reach the end of their stroke.

DIRECT AND INDIRECT MOTION

If the valve motion is indirect and the main valve has outside admission, the forward motion eccentric would follow the main crank pin about 90 degrees. If the valve is inside admission the forward motion eccentric would lead the main crank pin about 90 degrees. With direct valve motion and an outside admission

valve, the forward motion eccentric would lead the main crank pin about 90 degrees. With an inside admission valve the go-ahead eccentric would follow the main crank pin about 90 degrees.

Remember with balanced compound engines, the eccentrics are set in relation to the low pressure crank pins.

WALSCHAERT VALVE GEAR

The Walschaert valve gear, as shown in Fig. 21, derives its motion from the crosshead and the main crank pin. These two motions are so combined as to produce a motion similar to that obtained from the Stephenson gear.

The reversing link, however, is supported at its center by trunions which oscillate in stationary bearings. The link may, therefore, be swung back and forth, the center of the link remaining in a stationary position while the top and bottom of the link move back and forth.

An eccentric crank or crank arm is fastened to the main crank pin outside the main rod. An eccentric rod connects this crank arm to the bottom of the link, so that as the main crank pin revolves with the driving wheel, the link is swung back and forth in its support. A link block operating in the link slot, in the same manner as with the Stephenson valve gear, is attached to what is called a radius bar or rod, the other end of this rod connecting at or near the top end of a combination lever, the bottom end of the combination lever being attached to the crosshead. When the link block is moved either to the top or bottom of the link slot, any movement of the link backward or forward will be transferred to the radius bar and the top end of the combination lever. The cross-head moving back and forth in its guides causes a corresponding movement of the lower end of the combination lever. A valve rod or valve stem connected to the main valve in the steam chest is also connected to the combination lever or connection leading thereto, so that any movement of the combination lever will be transferred to the main valve, causing it to be moved back and forth to correspond to the movement produced in the combination lever by both the radius bar and the crosshead.

The reversing shaft arm is connected to the radius bar in such a manner that the end of the radius bar connected to the link block may be raised and lowered as the reverse lever is moved back and forth in the cab.

The above described valve gear is placed on the outside of the frames, is much lighter in construction and more convenient for oiling, inspection and repairs, than the Stephenson valve gear.

The slot in the link, like that of the Stephenson gear, is not straight. The radius of the link slot equals the length from the center of the link block to the center of the combination lever pin, these two points are connected to the radius bar. Since the radius bar has a flexible connection to the combination lever, if the link is in a perpendicular position the link block may be moved from one end of the link slot to the other, carrying with it the

radius bar. However, that end of the radius bar attached to the link block would describe a circle corresponding to that of the link slot, consequently the opposite end of the radius bar would remain stationary and no movement would be imparted to the valve rod or valve. This is the condition when the crank pin is on either its forward or back dead center; it will thus be seen that the reverse lever may be moved from extreme full forward to extreme full backward position without changing the position of the main valve upon its seat.

VALVE LEAD

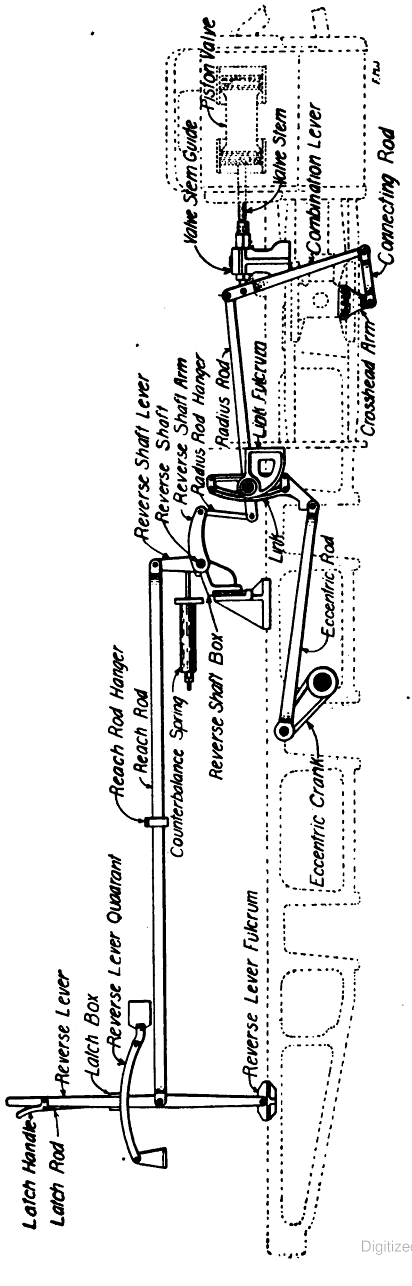
The amount of lead opening which the valve has when the crank pin is on either dead center, in which case the link stands in a vertical position, would be the same with the reverse lever in any position in its quadrant, therefore, moving the reverse lever from its extreme full forward or backward position toward the center would not change the lead opening.

It will be found in some cases that the valve rod is connected to the top of the combination lever and the radius bar connection is between the valve rod connection and the crosshead connection to the combination lever. If the valve is inside admission, the radius rod is connected to the top of the combination lever above the valve rod. If the main valve is outside admission the radius rod is connected to the combination lever below the valve rod connection. This would simply reverse the position of the main valve with relation to the steam port in order that the valve will open the steam port at the proper end of the cylinder.

According to the above description, if the link block is exactly in the center of the link slot, any motion of the link back and forth would not produce a movement of the radius bar; consequently if the combination lever is disconnected from its crosshead the crank pin could be revolved without imparting any movement whatever to the main valve. On the other hand, if the link block is in this same position and the crosshead moves back and forth, the radius bar connection to the combination lever would remain stationary, which would cause the valve rod to be moved back and forth as the crosshead moves.

As stated before, when the main crank pin is on either dead center, the lead opening from the steam chest to the cylinders is the same with the reverse lever in any position in its quadrant. This is due to the fact that the combination lever moves the valve an amount sufficient to open the steam port for the amount of lead given the valve at both ends of the cylinder, without any motion whatever being transmitted from the crank pin to the valve rod. With the valve on the center of its seat, its outside edges overlap the outside edges of the steam ports, the combination lever then must move the valve on its seat equal to the amount of valve lap, plus the lead opening. It can be said, therefore, that the combination lever overcomes the amount of lap and lead given the main valve.

When the link block is moved away from its position in the center of the link slot, any movement of the link back and forth is transmitted to the radius bar, which moves the top end of th



Piston Valve
Valve Stem Guide
Valve Stem
Combination Lever
Connecting Rod
Crosshead Arm
Link Fulcrum
Radius Rod
Radius Rod Hanger
Reverse Shaft Arm
Reverse Shaft
Reverse Shaft Lever
Link
Eccentric Rod
Reverse Shaft Box
Counterbalance Spring
Reach Rod
Reach Rod Hanger
Eccentric Crank
Eccentric
Reverse Lever Fulcrum
Reverse Lever Quadrant
Latch Box
Reverse Lever
Latch Handle
Latch Rod

FIG. 21.

combination lever with it, transmitting this motion to the valve rod and the main valve. The duty of the crank arm is therefore to transmit motion to the main valve so that it will be moved back and forth on its seat to admit steam to, and exhaust it from, the cylinder at the proper time, in relation to the piston movement in its cylinder. In order to increase or decrease the lead opening with the Walschaert valve gear it is necessary to change the distance between the radius bar connection and the valve rod connection at the combination lever, or the distance from the radius rod connection and the connection of the combination lever to the union link.

REVERSING

In Fig. 21 the main crank pin is shown in the front center position and the link standing perpendicular. Now suppose the crank pin to be moved to the bottom quarter position, the eccentric crank would move the bottom of the link forward and the top backward. If then the reverse lever was moved to its full gear forward position, the link block and back end of the radius rod would be lowered, moving the radius rod forward. This movement would be transmitted to the top of the combination lever, the valve stem and valve. The valve would therefore be moved forward to open the steam port to admit steam to the front end of the cylinder and connecting the back end of the cylinder to the exhaust. If the reverse lever is moved to its full back gear position, the link block and back end of the radius rod would be raised to the top of the link. This would cause the radius rod to be pulled backward, moving with it the combination lever, valve stem and valve, moving the valve to a position to admit steam to the back end of the cylinder and connecting the front end of the cylinder to the exhaust.

BAKER VALVE GEAR

The Baker valve gear is an outside gear, similar to the Walschaert gear, except that it has no reversing links or sliding blocks, the motion is derived from the crosshead and the eccentric arm or crank attached to the main crank pin, the same as the Walschaert valve gear. This gear is shown in Fig. 22.

In place of the reversing link, such as is used with the Stephenson and Walschaert valve gears, the Baker valve gear employs a bell crank and a system of hangers. A combination lever 15, connects to the crosshead 1 at its lower end, while the top end of the lever connects to the valve rod 18. Btween these two points is a connection of the combination lever 15 to the lower arm of a bell crank 3, the eccentric rod 9 connected to the eccentric arm 8 also connects to what is called a gear connecting rod 10. The top end of the gear connecting rod being connected to the upper arm of the bell crank 3, to which the combination lever 15 is connected. Approximately midway between the eccentric rod connection and the bell crank connection the gear connecting rod 10 is connected to a hanger 2, or radius rod, the gear connecting rod is therefore

free to swing back and forth as the eccentric rod is moved by the eccentric arm or crank. As the crosshead moves back and forth, the valve rod 18 is moved back and forth by the combination lever 15. The point of suspension of the radius bar or hanger 2 is such that as it is swung back and forth by the gear connecting rod, the connecting rod is lifted up and down, this motion is imparted to the upper arm of the bell crank 3, which causes the lower arm of the bell crank to swing back and forth, therefore motion is imparted to the valve rod 18 both by the crosshead and the eccentric rod. The radius bar or hanger is attached to a reversing arm or yoke 27, which in turn is attached to the reversing shaft 21, operated by the reach rod 17 and 13; and the usual reversing lever in the cab.

When the crank pin is on either dead center a movement of the crosshead from one end of its guides to the other causes the valve to move the amount of lap given the main valve, plus the lead; the same as for the Walschaert valve gear. When the crank pin is on either the front or back dead center the lead to the cylinder is the same for all positions of the reverse lever. The Walschaert gear and the Baker gear therefore have a constant lead. This means that moving the reverse lever from the full forward or backward motion toward the center does not change the amount of lead opening when the crank pin arrives at either dead center.

REVERSING

With the Baker valve gear the essential difference in the arrangement of the gear for inside and outside admission valves is that for an outside admission valve the reverse yoke is in front of the bell crank, and for inside admission valve the reverse yoke is behind the bell crank, the bell crank being reversed.

Referring to Fig. 18. If the crank pin is on the bottom quarter position and the reverse lever is moved to its full forward gear position the reverse yoke will lower the radius rod and also the horizontal arm of the bell crank. The lower or perpendicular arm of the bell crank will be moved backward, transferring this motion to the combination lever 15, the valve rod 6, valve stem 24, and the main valve. The main valve would therefore be moved to admit steam to the front end of the cylinder and connecting the back end of the cylinder to the exhaust. If the reverse lever is moved to the full back gear position the reverse yoke would raise the radius rod and the top or horizontal arm of the bell crank moving the lower arm of the bell crank forward, this motion is transferred to the main valve, which is moved to a position to admit steam to the back end of the cylinder and connecting the front end of the cylinder to the exhaust.

VALVES

Common Slide Valve

The ordinary slide valve commonly known as the "D" type valve, on account of its shape, has a cavity in its center to control the exhaust steam from the cylinders.

The common unbalanced "D" slide valve is subjected to considerable pressure on its seat, on account of the steam pressure acting upon its entire upper surface. This presses the valve tightly on its seat, causes the valve and seat to wear rapidly and also increases the friction between the valve and seat, and the difficulty of lubricating the same. Oil should therefore be fed to the valves regularly and in sufficient quantity to insure proper lubrication. When the valves get dry, due to lack of lubrication or on account of working water through the cylinders, the work of the valve gear is increased considerably, this causes increased wear on all moving parts, tends to distort the various parts of the gear, making the engine sound lame, reducing the power of the engine and increasing the consumption of fuel and water.

In order to overcome these disadvantages, as far as possible, a type of slide valve known as the balanced slide valve was developed from the ordinary "D" type valve. This type of valve is shown by Fig. 23, and is used on a great many locomotives. The slide valve shown in Fig. 23 is balanced by applying strips along its upper edges which bear against a plate on the steam chest cover, and fit closely in grooves cut in the top of the valve's body. The space on top of the valve between the strips is connected to the exhaust passage, thus the pressure in the steam chest is excluded from a greater part of the valve's surface, reducing its resistance to movement on account of the reduced friction and the ability to better lubricate the wearing surfaces.

The strips above mentioned fit closely against each other at the ends and also fit the grooves on their inside edges, the steam pressure tending to force them together, thus making a steam tight joint. Springs underneath the strips provide for holding them against the pressure plate at all times.

In some cases slide valves are balanced on the same principle as outlined above, instead however, of cutting grooves along the side and ends at the top of the valve for applying strips, the top of the valve is built up in circular form, a groove is then cut near the outside edge which provides for a ring similar to a packing ring, being inserted in this groove, the ring bearing against the plate on the steam chest cover and in the groove performs the same duty as the balance strips.

In Fig. 23 is shown the balance strips and balance plate as used with an ordinary balanced slide valve. In the plain slide valve the port through the valve and the balance strips and plate are omitted.

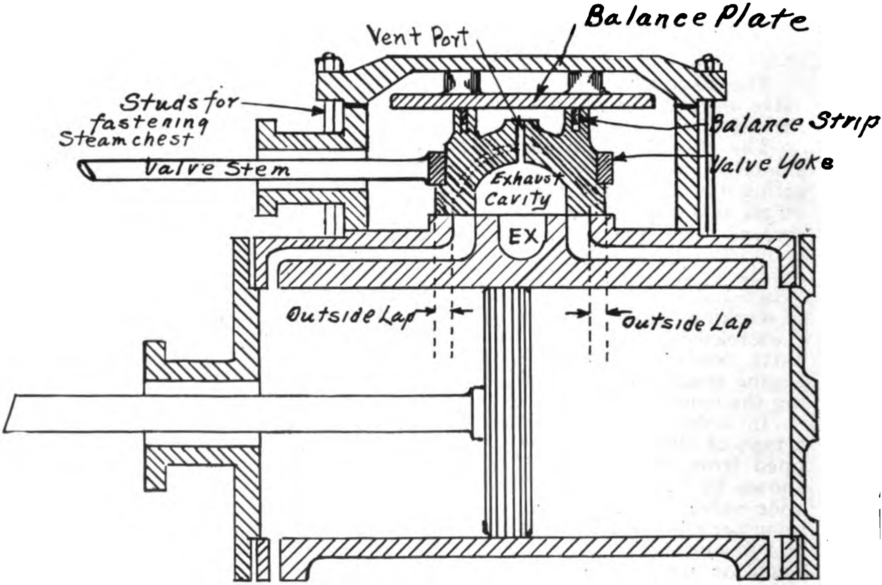


FIG. 23.

The Allen ported slide valve is of the same type as the balanced "D" valve, except that it has a steam port cored through the valve over the exhaust port, the slide valve seat being so arranged that when the valve opens the admission port at its admission edge the opposite side of the slide valve travels over the edge of the slide valve seat. The steam thus admitted into the cored passage, passes over the top of the exhaust cavity to the cylinder. This valve is clearly shown in Fig. 24.

The Allen ported slide valve, Fig. 24, is designed to prevent as far as possible the wire drawing of steam when working the valve at short cut-offs at high speeds, its general design is the same as the balanced "D" slide valve. The idea being to provide as large an opening as possible between the steam chest and cylinder. The effect of wire drawing the steam is to restrict its free flow from the boiler to the steam chest, or from the steam chest to the cylinders. It reduces the possible work that could be performed by the steam if no wire drawing took place. In other words, if the throttle was wide open it might be possible to maintain 200 pounds pressure in the cylinder at the beginning of a piston stroke, if the boiler pressure was 225 pounds; while if the throttle was only partly open

the boiler pressure may be 225 pounds while the highest pressure in the cylinder may be only 100 pounds.

It will be understood from a description of the various valve gears that the travel of the valve upon its seat is shortened as the reverse lever is moved toward the center of its quadrant, the steam ports are therefore not opened as wide as when working at full stroke. The steam under these conditions has access to the cylinders through a restricted port opening. In order to increase the port opening without providing for a greater movement of the valve, or a longer cut-off, the Allen valve is provided with the port which opens at the valve face on each side of the exhaust cavity, thus when the valve opens the steam admission port, say ½", the cored passage through the valve is also opened to the same port a like amount. The opposite side of the valve over-travels the edge of the valve seat to permit the steam from the steam chest to pass through the cored passage in the valve. This valve is illustrated in Fig. 24.

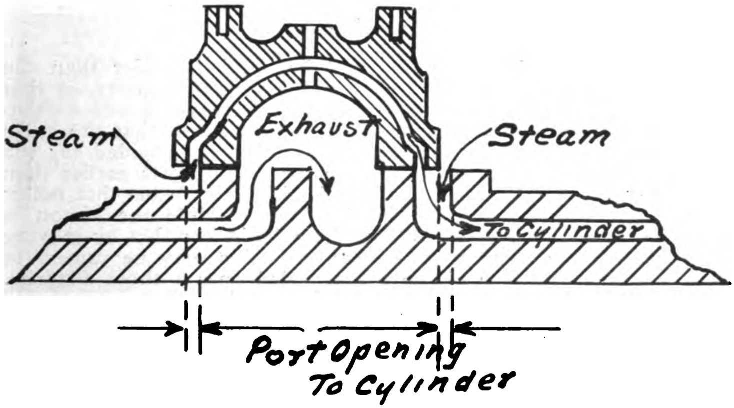


FIG. 24.

PISTON VALVE

A piston valve is of circular cross-section, having two or more heads or spiders for directing steam to the proper ports. The different heads are fitted with packing rings similar to and for the same purpose as the rings on the main steam piston. It operates in a cylindrical chamber or bushing and will give greater port opening for the same movement than will a slide valve of equal weight. Such a valve is clearly shown in Fig. 25.

If the live steam from the boiler passes to the cylinders between the two heads of a piston valve, the valve is of the inside admission type. However, if the steam passes to the cylinders at the ends of the valve, the valve is of the outside admission type.

Slide valves are attached to the valve motion by a valve yoke, which passes around the slide valve and attaches to the valve steam, while a piston valve is connected to the valve motion by a valve stem which passes through the valve somewhere near its center in the same manner as fastening the ordinary piston to the piston rod.

VALVE LAP

It will be noted in Fig. 24 that the valve is wider than the distance between the outside edges of the admission ports, so that when the valve is placed on the center of its travel it will overlap the outside edges of the steam ports. The amount that the valve overlaps these ports is called steam lap, and is provided for the purpose of causing the valve to close the steam ports earlier than would be the case if no lap was provided. This means that boiler pressure may be admitted to the cylinders while the piston is traveling its full stroke throughout the cylinder, or that by moving the reverse lever toward the center the valve may be caused to close the port after the piston has traveled only a short distance. The steam pressure then in the cylinder is allowed to expand and thus push the piston to the end of its stroke through the expansive power of the steam.

CYLINDER ARRANGEMENTS

The arrangement of cylinders differs for the various designs of locomotives, the simple engine has only two cylinders, one on each side, in which case steam which is used to force the piston from one end of the cylinder to the other is then exhausted through the valve to the exhaust ports in the cylinder saddles and to the smoke stack and the atmosphere. The cylinder saddle is that part of the cylinder casting between the frames to which the front end of the boiler is attached.

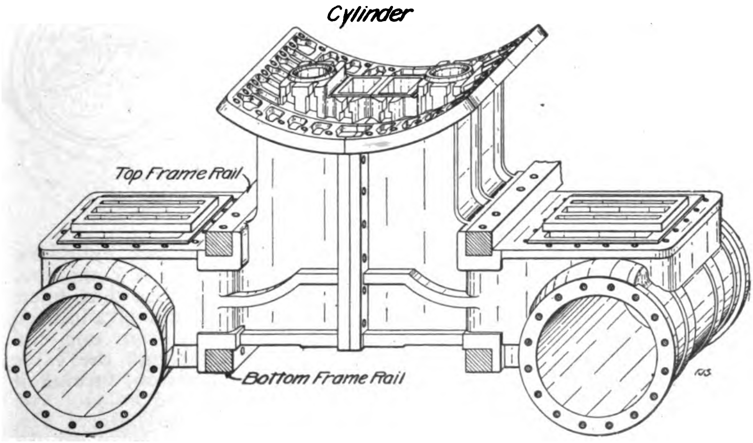


Fig. 26.

It can be seen from this description that the simple engine uses steam only once after it is admitted to the cylinder. Figs. 26 and 27 show typical simple cylinders. The cylinders of Fig. 26 are for a slide valve engine, that of Fig. 27 are for piston valves.

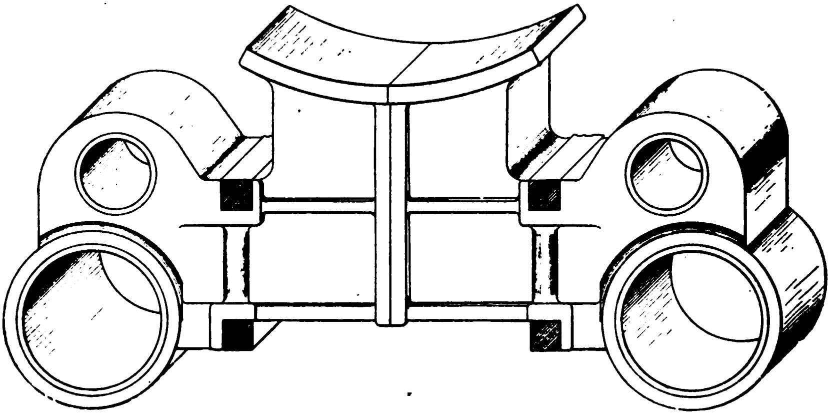


Fig. 27.

Other types of locomotives employ more than two cylinders. These types being known as compound locomotives. A compound engine has the advantage of expanding the steam more than once, that is, the cylinders are so arranged that the steam is admitted first to one cylinder and after forcing the piston from one end to the other of its stroke, it is then exhausted through the valve into another cylinder where it acts on a second piston, forcing it throughout its cylinder.

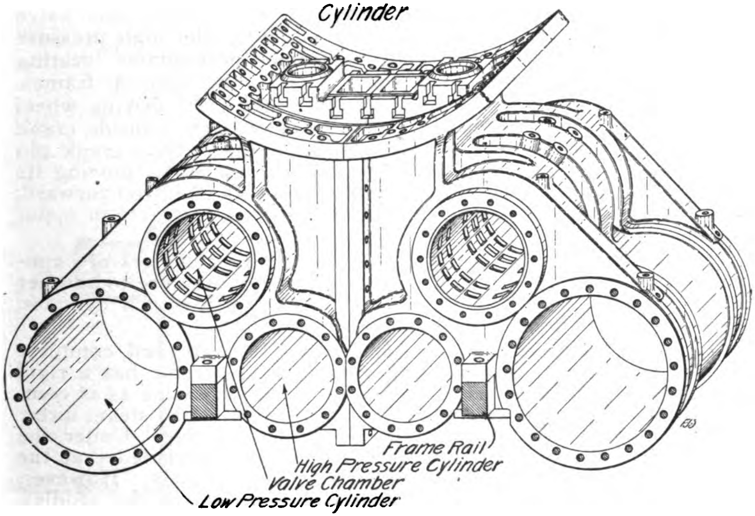


FIG. 28.

With the balanced type of compound locomotive, a pair of cylinders for which are shown in Fig. 28 the high pressure cylinders are located between the frames, while the low pressure cylinders are located outside the frames. The balanced compound has a single valve on each side which admits steam from the boiler to the high pressure cylinder, conveys it from the high pressure cylinder to the low pressure and then to the exhaust. This valve is composed of three hollow spools, all attached rigidly to the valve stem.

With the compound engine, the high pressure cylinders are of comparatively small diameter, and receive the steam pressure directly from the boiler. The low pressure cylinders are larger and receive the steam which is exhausted from the high pressure cylinders; the low pressure cylinders being made considerably larger than the high pressure in order that the reduced steam pressure will have a much larger piston area to act upon in order that the lower pressure will develop about the same power on the low pressure piston as is developed by the boiler pressure upon the high pressure piston. After passing through the low pressure cylinders the steam is exhausted to the stack.

In Fig. 28 is shown the arrangement of cylinders and valve chambers for the balanced compound engine. The high pressure cylinders being located between the frames necessitates locating the high pressure main rods and crank pins also between the frames. The axle is built up in the form of two cranks, the driving wheel being attached to the axle in such a manner that the inside crank is directly opposite, or one half turn from the outside crank pin on the same side; so that as the outside crank pin is moving its rod backward, the inside crank pin is moving its main rod forward, which causes the high and low pressure pistons to travel in opposite directions.

In the Mallet compound, the high pressure cylinders are connected to one set of driving wheels, and the low pressure to another set. The Mallet compound has a main valve for each cylinder. This type of compound is shown in Fig. 29.

In the Mallet type of compound, two separate and complete engines are under one boiler. The rear engine frame has a rigid connection to the cylinder saddles and boiler, the same as is common to other types of locomotives. This engine works steam direct from the boiler, the same as the simple locomotive. Under the front end of the boiler is another engine, so constructed that the cylinders are fastened rigidly into the engine frames. However, the front part of the boiler is not attached to the cylinder saddles, but rests upon supports placed on top of the engine frame; these supports being so constructed that the boiler may slide from side to side. The rear end of the front engine frames are fastened rigidly to a large casting which reaches back into a casting fitted into the front end of the rear engine frames. These two castings are connected by a large center pin. This permits the front end of the front engine and its frames to swing from side to side under the boiler, as the engine is rounding curves; the rear engine in this case being the high pressure engine and the front engine being the low pressure engine, the steam being carried from the high pressure engine to the low pressure engine through suitable pipe connections having flexible joints to care for the movement of the frames and cylinders between the two engines.

In order that the full power of the low pressure cylinders may be utilized in starting a compound engine, a connection called a "starting valve" is used. This connection on a balanced compound engine permits live steam at one end of the high pressure cylinder to pass to the opposite end of the same cylinder. When steam is being admitted to one end of the high pressure cylinder, the opposite end is connected to the low pressure cylinder through the valve in the valve chamber, therefore the starting valve by-passes live steam through the high pressure cylinder and valve to one end of the low pressure cylinder. This connection permits of using boiler pressure in the low pressure cylinder through a connection much smaller than the ordinary steam port leading from the main valve to the cylinder.

In the Mallet type of compound the starting valve is located in the cab, a pipe connection leading therefrom to the low pressure steam pipe between the high pressure and low pressure engines.

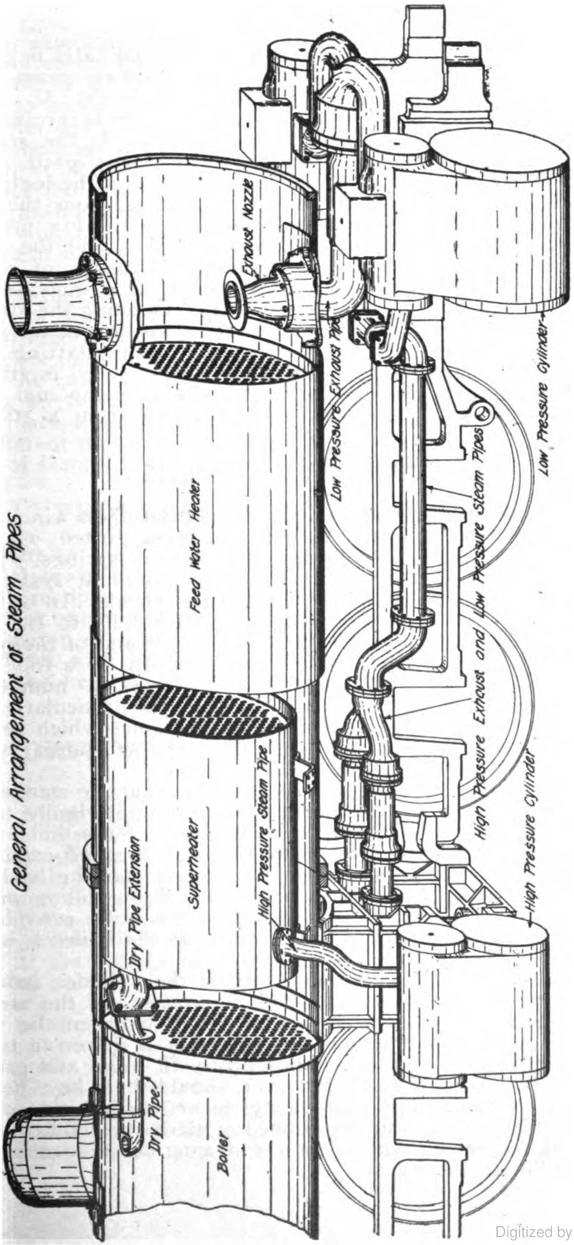

General Arrangement of Steam Pipes
Exhaust Nozzle
Feed Water Heater
Superheater
Dry Pipe Extension
Dry Pipe
Boiler
High Pressure Steam Pipe
Low Pressure Exhaust Pipe
Low Pressure Steam Pipes
High Pressure Exhaust and Low Pressure Steam Pipes
High Pressure Cylinder
Low Pressure Cylinder

FIG. 29.

In other types of compound locomotives the starting valve is merely a plug cock in a pipe connection between the two steam ports leading to the high pressure cylinders, as shown in Fig. 32. A rod connects the starting valve to a lever in the cab to provide for opening and closing the starting valve at will. If the starting valve is left open after the engine reaches a sufficient speed so that the starting valve cannot pass steam from one end of the high pressure cylinder to the other, as fast as it passes from the high pressure cylinder, through the valve chamber, to the low pressure cylinder; the engine is really working compound and the steam passing through the starting valve is wasted, causing, of course, a waste of fuel and water; and at the same time increases the back pressure in the high pressure cylinders. Opening the starting valve at low speed and very heavy work tends to set up undue stresses in the frames and cylinder castings. The starting valve should, therefore, be closed as soon as sufficient speed is attained so that the engine can handle the train working compound. The starting valve should be opened when starting from a state of rest.

LOCOMOTIVE FRAMES

The main locomotive frame is the foundation upon which rests the boiler and cylinders, the frames being supported over the driving axles and truck wheel axles by a system of springs.

The main frame is comprised of two heavily built systems of rails, one on each side just inside the driving wheels. In order to hold them rigidly in place they are fastened solidly to the main cylinder saddle casting, which supports the front end of the boiler. At the rear end they are fastened together rigidly by a foot plate or deck casting, and with modern locomotives, a number of intermediate frame braces are applied. This is particularly true on engines having the valve gear outside the frames which permits plenty of room between the frames for applying substantial braces from one frame rail to the other.

The boiler is, of course, secured to the frames at the smoke box, which is the front part of the boiler, by bolting it rigidly to the main cylinder saddle casting. The firebox end of the boiler rests upon brackets attached to the frames, which are called expansion brackets or furnace bearers; in such a manner that the back end of the boiler may move forward or backward by sliding on the above mentioned brackets. This construction is to provide for the expansion and contraction of the boiler, as the boiler is longer when hot than when cold.

Usually that part of the frame to which the cylinder saddle is bolted has offsets into which is fitted the corners of the saddles, and it is the practice to apply a tapered key between the offset in the frame and the cylinder saddle. This key is driven in tightly in order to hold the cylinder saddles firmly in place and prevent their movement back and forth, however, should these keys become loose or lost, a noticeable pound may occur on that side of the engine. Such keys should be maintained in place and tight, in order to reduce the shearing strain on the frame bolts securing the cylinder saddles to the frames.

The expansion bracket, or furnace bearers, located at the firebox end of the boiler, are so arranged that while they hold the back end of the boiler in place, they provide for that end of the boiler to move back and forth to take care of the lengthening of the boiler due to expansion when it is hot. These parts should be maintained in good order and lubricated, to provide for a free movement of the boiler, with respect to the frames, otherwise there is a possibility of loosening or breaking the expansion brackets or of causing leaks in the boiler seams, particularly at the throat sheet, mud ring, staybolts and flues. In some types of engines, with deep fireboxes which set down between the frames, the expansion brackets are placed on top of the frames and secured to the side sheets, such brackets being built up in the form of angle irons. In other cases the firebox end is supported by pads which loop around the frame, being fastened to the firebox sheets above and below the frame.

In the case of a broken frame it is advisable not to attempt to handle anything but a very light train, particularly if pounding takes place when the engine is working. Instructions are in effect on different divisions regarding the method of handling engines in cases of frames being broken. Be goverened by such instructions.

PEDESTAL BRACES OR BINDERS

Fitted in the bottom of the frame jaw is what is termed a pedestal brace or binder, for the purpose of preventing the jaws from spreading and to hold the shoes and wedges in place. The shoes are snugly fitted between the above mentioned binder brace and the top of the frame jaws to prevent them from working up and down with the driving box. The pedestal brace or binder should be kept absolutely tight to prevent working of the frame jaws.

DRIVING BOXES, SHOES AND WEDGES

Jaws are provided in the main frame into which fit the driving boxes which rests upon the driving axles. These driving boxes are free to move up and down in the jaws. In order to care for the wear of the driving box faces and prevent wearing the jaws in the main frame, also to provide for maintaining the driving axles in proper alignment with the frames, a metal shoe is interposed between the driving box face and the frame. On the opposite side of the driving box the frame jaw is tapered, that is, the jaw is wider at the bottom than at the top. Another metal shoe is also provided on this side of the driving box, which is called a driving box wedge. This wedge conforms to the face of the box and to the taper of the frame jaw. Raising this wedge between the frame jaw and driving box forces the driving box against the shoe on the opposite side. This provides for fitting the driving box closely in each side of the frame jaw and also permits of taking up any lost motion in the driving box faces due to wear.

The wedge fitted between the driving box and the frame is so constructed that it may be moved up and down by a wedge bolt

extending through the binder brace. Turning the wedge bolt nuts, fitted to the wedge bolts, causes the wedge to be raised or lowered in the same manner as operating a screw jack, that is, if the nut on top of the binder is turned in the direction to raise the wedge bolt, after loosening the nut at the bottom, the wedge will be forced upward. If, however, the nut at the bottom of the wedge bolt is turned in a direction to pull the wedge bolt down, after loosening the top nut, the wedge will be pulled downward. After the wedge has been located in the desired position, screwing both the top and bottom wedge bolt nuts tightly against the binder securely locks the wedge in that position.

The driving box is free to move up and down between the driving box shoe and wedge, and since the driving boxes, shoes and wedges are all of metal, the wearing surfaces must be regularly lubricated, in order to reduce the wear and to provide for free movement of the parts.

In most cases the wedge bolt hole through the binder or pedestal brace is drilled and tapped, the wedge bolt being screwed into this hole. In such cases it is necessary to turn the wedge bolt in order to raise or lower the wedge. A jam nut is applied to the wedge bolt which may be loosened to permit of making necessary adjustments, after which the nut is screwed tightly against the binder or pedestal brace to firmly lock the wedge bolt in the desired position.

In adjusting wedges to take up lost motion it is necessary that the driving box be forced against the driving box shoe, otherwise the wedge may be moved up tightly between the frame and box and still leave some lost motion in the driving box between the shoe and wedge. In order to accomplish this the crank pin may be placed on the top quarter and the throttle opened slightly in order to pull the driving box tightly against the shoe, the reverse lever to be placed in either the forward or back motion, depending on whether the wedge is located in front of the driving box or behind it. Ordinarily the wedges are located behind the driving box. In order to avoid blocking the engine to accomplish this, cut out the driving brakes and fully apply the tender brakes. The engine should always be upon a piece of straight level track when preparing to set up wedges.

In setting up the wedges consideration must be given to the temperature of the driving box. If the boxes are at normal running temperature, after the engine has just been run a considerable distance, which is the best time for setting the wedges, the wedge may be adjusted closer than is the case if the driving boxes are cold and engine has been standing for a considerable period of time. It must be remembered, of course, that when the driving box warms up it expands and tends to tighten itself between the two faces of the driving box shoe and wedge, and if the wedge is set up too close when the driving boxes are cold, expansion may cause the driving box to stick between the faces of the shoe and wedge.

If it is found that a wedge bolt is broken, the wedge may be held in place by splicing the wedge bolt with a nut, that is, screwing a nut to one of the broken ends, then placing the two ends of the broken bolt together and screwing the nut on the bolt until the broken part of the bolt is inside of the nut. If this is impossible

the wedge may be raised to the proper height, then placing a block between the bottom of the wedge and top of the binder or pedestal brace, securing the block firmly to the latter.

If the wedge has been set up too tight, or the shoe and wedge faces are not properly lubricated, the driving box will not move freely between the shoes and wedges. This may cause driving box to heat up badly on account of the load shifting due to inequalities in the track. It also causes the engine to ride badly, and is more or less damaging to the journals, driving box and frame. In cases of this kind it is advisable to loosen the wedge as soon as possible and get it down so that the driving box may move up and down freely. If it cannot be pulled down with the wedge bolt, pull down as much as possible on the wedge bolt and then run the driving wheel ahead or back of the one with stuck wedge over a nut or other piece of metal. In some cases it may be necessary to slack off on the binder bolts, and run the wheel over the block, as stated before. In case the binder or pedestal brace is loosened it should be firmly tightened, after the wedge has been adjusted so that it will not stick again. In all such cases the binder bolts should be reported tightened on arrival at terminal. It may be possible some times to loosen a wedge after it has become stuck by applying some signal oil or kerosene oil to lubricate it, or pull down on the wedge bolt as far as possible, oil the shoe and wedge and proceed. The tendency of the driving box to move up and down will in many cases loosen the wedge soon after starting.

In case excessive lost motion in the attachment of the wedge bolt to the wedge interferes with holding the wedge in the desired position, a block may be placed between the wedge and binder brace to raise the wedge to the desired position, then pull down on the wedge bolt until the wedge is solid on the block and tighten the jam nut on the wedge bolt.

The Automatic Adjustable wedge, shown in Fig. 30, is designed to adjust itself automatically to the wear of the driving box, shoe and wedge faces.

This device consists of an adjusting and a floating wedge held in proper relationship by a coil spring. The adjusting wedge is tapered on one side to suit the taper of the pedestal jaw and on the opposite side to accommodate the lesser taper of the floating wedge.

To the adjusting wedge is attached the wedge bolt. This bolt passes down through the pedestal binder and the spring bracket attached to the binder. An adjustable spring cap is mounted on the wedge bolt with the spring between the cap and the bracket. The spring holds the adjusting wedge in position and automatically maintains proper adjustment of the driving box.

Between the double tapered adjusting wedge and the driving box is placed an oppositely-tapered floating wedge. This floating wedge is from 3-16 inch (minimum) to 5-16 inch (maximum) shorter than the distance between the binder and frame rail.

When the box moves up or down the floating plate is carried with it until it strikes the frame or binder. On the upward movement this gives relief between the floating wedge and adjusting wedge. On the downward movement the floating and adjusting wedges will move together and the taper on the back of the adjusting wedge will give relief.

The springs are properly adjusted when applied and do not require any adjusting as is common to other types of wedges.

It is important that the automatic wedges be properly lubricated. For this purpose a small oil well is provided at the side on top of the driving box, which is packed with curled hair having a layer of waste on top of same. This well should be kept supplied with engine oil. See that oil is applied liberally to the oil well on each driving box before beginning each trip, also oil the edges of the driving box on each side so that oil will be supplied directly to the shoes and wedges. Remember that the driving box fits snugly between the shoe and wedge at all times and that the matter of lubrication for the wearing surfaces is one that must not be neglected if rapid wear of the parts and sticking of the adjustable wedge is to be avoided.

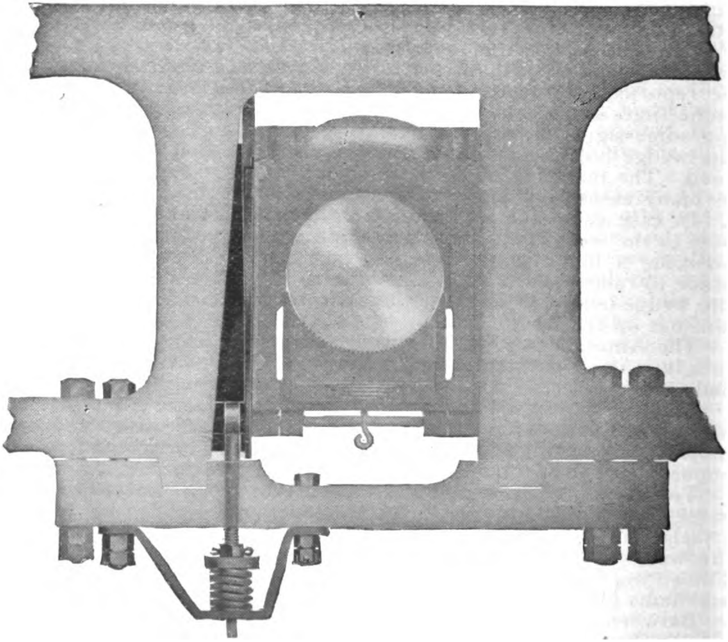


FIG. 30.

DRIVING AND TRUCK SPRING RIGGING

Resting on top of each driving box and reaching considerably above and spanning the top frame rail, is what is called a spring saddle. This spring saddle is so constructed that one leg of the saddle rests on top of the driving box outside the frame rail, the other leg resting on top of the driving box inside the frame rail. The driving spring then rests on the spring saddle. This provides for the driving box to move up and down in its jaw, carrying with it the spring saddle. To the ends of the driving spring are attached flat bars called spring hangers; these spring hangers attach either to the main frame or to the end of equalizing levers, or the equalizing levers are attached to the main frame at or near the middle of the equalizers. In this way the main frame is supported on the spring hangers, equalizers and springs, the spring saddles providing for the necessary movement of the driving boxes in the frame jaws to care for the action of the driving springs. This arrangement also permits the weight of the locomotive to be distributed among the various pairs of wheels so that each pair will carry its share and no more.

In some cases a four wheel truck supports the front end of the engine, this truck being located directly under the cylinder saddle casting. In such cases an independent system of spring rigging is included in the construction of this truck. It is also the practice on large locomotives, to apply a trailing truck behind the back driving wheels, to support the back end of the locomotive. When a trailer truck is used, the spring rigging supporting the frame over the trailer is connected through a system of equalizing levers to the spring rigging over the driving boxes. When a two wheel truck is used at the front end of the engine, the spring rigging of this truck is connected to the driving spring rigging through a system of equalizing levers. Fig. 31 shows the main frames and two systems of springs referred to above. Note that the left hand frame does not show the same spring arrangement as the right hand frame. In applying either of the spring riggings shown, to a locomotive, the same arrangement as shown on the left would be used on both sides, or both sides would be equipped with the arrangement shown on the right.

BREAK-DOWNS—GENERAL

Engineer's Duty

An engineer's first duty in case of a break-down which necessitates stopping, is to see that the train is properly protected against other trains, and next to see that the main line is cleared as soon as possible, and proper report made, giving details of the trouble being experienced, with the probable length of time to get the engine moving and what work the engine will be able to perform after ready to proceed.

Should anything occur which would necessitate stopping a train for inspection of any parts which does not require a stop at once, the engineer must always consider his ability to start the train readily after making such stops, and should avoid, if possible, stopping at places where it is difficult to start.

Before disconnecting in the case of any break-down, determine how long it will take to put the engine in condition to move, what work the engine can do and whether another engine is readily available to take the train. Do not start to disconnect if it will cause additional delay after relief engine arrives before the work of disconnecting can be completed. In such cases only disconnect those parts necessary to provide for the engine being towed.

BREAK-DOWNS—STEPHENSON VALVE GEAR SLIPPED ECCENTRICS AND IRREGULAR EXHAUSTS

In case anything occurs to prevent the main valve from admitting steam to or exhausting it from the cylinder at the proper time, the exhausts will be irregular, in which case the engine is said to be lame. The most frequent causes of an engine being lame are: Eccentrics out of adjustment on the axle. Eccentric rods out of adjustment where fastened to the eccentric straps, rocker box loose on their supports; eccentric strap bolts loose; a cracked or broken valve yoke, if the engine has slide valves; or a broken valve or valve ring if the engine has piston valves; valve loose on valve stem or lack of lubrication which makes the valve very difficult to move on its seat. The link may be broken at one end. Do not confuse heavy and light exhausts for irregular exhausts, the engine may be square and still have one or more heavy exhausts, the others being normal.

In order to determine which eccentric is slipped, the reverse lever may be placed in full forward motion, applying the brakes and moving engine slowly. If the engine is square with the reverse lever in full gear, but the exhausts become irregular as the reverse lever is hooked up or moved toward the center, the trouble would be in the back-up eccentric. It may be possible to determine which side of the engine is at fault by watching the crosshead and listening to the exhausts. If the engine is square an exhaust should occur as the crosshead reaches either end of its guide and as it passes the center of the guide in both directions.

passes the center of the guide in both directions.

Under the present method of fastening eccentrics on the driving axle, a slipped eccentric is a rare occurrence. The axles have slots or key-ways cut into them as have also the eccentrics, and a steel key is fitted into these key-ways. The two halves of the eccentric are fastened together with substantial bolts, and set screws are also placed through the eccentric, which are screwed firmly against the axle. Should an eccentric move out of its proper position on the axle due to the key being out of place, or shearing off, the eccentric may be placed near enough to proper adjustment by moving it around until the two key-ways, the one in the axle and the one in the eccentric, are together. This will permit the engine to handle the train to terminal, where repairs can be made. It might be that the axle will have two slots or key-ways cut in it, in which case the proper key-way to use can be determined by noting the other eccentric on the same side to see whether the eccentric is set to follow the main crank pin or to lead it, in other words, the eccentric should be set on the opposite side of the crank pin and the same number of wheel spokes from the crank pin, the crank pin to be mid-way between the two eccentrics. The reason for more than one key-way being found in the driving axle is that the valve motion is sometimes changed on account of applying new cylinders which have different types of valves, one being arranged to admit steam to the cylinder from the center or inside of the valve, and the other admits steam to the cylinder from the ends or outside of the valve.

If both eccentrics are slipped set them in the same relation to the crank pin as the ones on the opposite side of the engine, and the same number of spokes in the wheel from the crank pin.

When an eccentric slips out of place the exhausts will be irregular, and since the crank pins are placed one quarter of a turn from each other, and an exhaust takes place each time the crank pin arrives at the center, there should be an exhaust occur each time the crank pin arrives at the center and the top and bottom quarter. Watching the crank pin on either side as the engine moves slowly will locate the point at which the irregular exhaust occurs. There should be four exhausts for each revolution of the crank pin and they should occur with uniform regularity.

In case of a broken eccentric strap or rod, both eccentric straps on the disabled side should be taken down, the valve placed centrally on its seat to cover the steam ports and securely fastened in that position. The engine can then be operated on one side. The link should be fastened in an upright position if not disconnected from hanger.

In case of a broken rocker arm or valve rod it is only necessary to remove the broken parts, place the main valve centrally on its seat and fasten it securely in that position.

A transmission bar, which is really an extension leading from the link block to the valve rod or rocker arm, is applied to make a suitable connection between these two points The end of this bar, close to the link block is fastened to what is called a transmission bar hanger, to support the transmission bar at that point. If the transmission bar hanger should break, locate the link block in such a

position in the link as will provide for handling the train, placing a block in the link above and below the link block to hold the link block in the desired position; securely fastening the blocks to prevent their falling out. It may be possible to use a switch chain to support the transmission bar in place of the broken hanger. If the weight of the transmission bar is not sufficient to prevent its slipping up as the valve moves, a block may be placed between the transmission bar and the point of support inside the chain, so that it will swing with the chain and hold the transmission bar in position. If the transmission bar is broken between the link block and the valve rod or rocker arm connection, place the valve centrally on its seat, fasten it securely, remove the broken parts where necessary and proceed.

In some cases it may be found that the eccentrics are not located on the main driving axle, and in case it is necessary to take down the side rods, it is necessary to prepare the engine to be towed in.

BROKEN VALVE YOKE OR STEM

In the event of a valve yoke or valve stem being broken, either with the ordinary slide valve or with the piston valve, if the crank pin is placed on either quarter and the reverse lever is moved from full forward to backward gear, with the throttle open slightly and the cylinder cocks open, steam will show only at one cylinder cock; while if the valve yoke or stem is intact steam will show alternately at each end of the cylinder as the lever is moved back and forth.

BROKEN ECCENTRIC STRAP OR ROD, REVERSE SHAFT ARM OR REACH ROD

In case of a broken eccentric, eccentric strap, eccentric rod, or link, take off both eccentric straps and rods on the disabled side, fasten the link by tying it to the link hanger or reverse shaft arm so that it cannot turn over and interfere with reversing the engine. Place the valve centrally on its seat and clamp the valve stem so that the valve cannot move. If the main rod is not taken down, take out the cylinder cock valves or block them open, also remove the indicator plugs in the side of the cylinder castings, so that oil may be applied to the cylinders and to relieve the compression to prevent the cylinders becoming hot. If some provision is not made to lubricate the cylinders, and prevent the churning of air back and forth without cool air being admitted, the cylinder may be very badly damaged.

If the reach rod, connecting the reverse lever to the reverse shaft arm is broken, put a short block in the top of one link, and a long one underneath the link block, securely fastening them in position so that the engine will work nearly full stroke. Do not block both links. The link blocks are held practically stationary at their support by the link block pins and as the eccentric rods move back and forth they carry with them the top and bottom of the link. The position of the eccentrics on the axle is such that when

the crank pin is on one center the eccentrics are in the front of the axle, and when on the other center they are behind the axle, therefore the entire link is moved back and forth even though the reverse lever be in its central position in its quadrant. The link is supported by the reverse shaft arms and link hanger, the latter connecting between the link saddle and the reverse shaft arm. The link saddle is fastened rigidly to the center of the link, therefore as the link hanger swings back and forth with the link, the link is raised and lowered slightly so that the link block must slip a very little in its slot. By holding up the reverse shaft arms the blocking placed in one link will hold up the link on the other side and the necessary slip of the link blocks will be provided for.

BREAK-DOWNS—WALSCHAERT VALVE GEAR BROKEN ECCENTRIC ROD OR CRANK

If the eccentric rod or crank should break, remove the broken parts, disconnect the radius bar hanger from the reverse shaft arm, block the link block in the center of the link. The combination lever will then move the valve the amount of the lap and lead, and will admit steam at both ends of the cylinder at the proper time, but only in proportion as the lead of the valve provides for. This will assist in moving the engine and lubricating the cylinder. See that the radius bar is blocked substantially so that the link block cannot move from its position in the center of the link.

If it is impracticable to block the link block in this manner disconnect the combination lever, move it forward against the back cylinder head and tie it securely in that position. See that the crosshead and all of its parts clear the combination lever throughout its movement in the guides. Disconnect the reverse shaft arm from the radius bar, allow the link block to drop to the bottom of the link. Now move the link so that the valve will be moved to a position on the center of its seat to cover the ports at both ends of the cylinder, then wedge between the link and its supporting frame or between the radius bar and the guide yoke or other convenient place so that the link will be securely held in that position.

BROKEN VALVE STEM, RADIUS BAR OR ROD

In the case of a broken valve steam or rod, if the moving parts attached to the combination lever and the valve rod or stem can be removed so that they will not interfere with the movement of the combination lever, and the combination lever is supported such as might be the case with a crosshead or other guide, it is only necessary to place the valve centrally on its seat and secure it there. If there is no support for the combination lever or if the movement of same would cause it to strike other parts when disconnected, take down the combination lever, disconnect the radius bar from the reverse shaft arm, raise the front end of the radius bar and fasten it to clear other parts. Then take down the eccentric rod and fasten the valve centrally on its seat.

If the radius bar hanger which holds up the radius bar should break, place the link block at a point in the link which will give the engine the necessary power to start and handle train. Place a block of wood in the link if possible, on each side of the link block, to hold it in this position. Secure the blocks so they will remain in position. Remove the broken parts and proceed. The engine should not be reversed without first changing the blocks on the disabled side.

If it is impracticable to block the link block in its proper position in the link, disconnect the eccentric rod and the bottom end of the combination lever and allow the radius bar to ride at the bottom of the link, place the valve on the center of its seat and securely fasten it there. Fasten the bottom of the combination lever to the cylinder head, or remove it, so it will clear the crosshead.

If the combination lever breaks, take down the radius bar hanger and the eccentric rod, and all other parts supported by them. Place the valve centrally on its seat and fasten it securely, and proceed on one side. If it is possible to connect the radius bar directly to the valve stem or valve rod so that it will provide for moving the valve, this may be done and the engine proceed working on both sides.

If the union link connecting the combination lever to the crosshead should break, disconnect the eccentric rod and the radius bar hanger to the reverse shaft; allow the radius bar to ride at the bottom of the link and fasten the combination lever to the cylinder head or remove it, so it will clear the crosshead. Then place the main valve centrally in its seat and fasten it securely in that position and proceed on one side.

BREAK-DOWNS—BAKER VALVE GEAR

Two means are provided for blocking the gear and valve in case of a break down. The valve stem crosshead in some cases is provided with a set screw that may be screwed down tightly to hold the crosshead in the desired position, if the valve stem is fastened to the crosshead so that the crosshead will hold the valve, this means may be used to block the valve in central position. Another way is to bolt the lower arm of the bell crank to the side of the gear frame, if the connections to the valve stem are intact this will hold the valve in place. See that the bell crank arms are blocked so that there will be no movement between the bell crank arm and the bolt. Some of the Baker valve gear frames have two holes drilled in them to provide for this method of blocking. It is possible to use wedges between the bell crank arms and the side of the gear frame in case bolts cannot be used. When the gear is blocked in this manner the following parts may fail without necessitating the removal of the combination lever of its connections:

The eccentric crank or arm, the radius rods, the reverse yoke, the short reach rod and the horizontal arm of the bell crank. Operating the engine with the gear blocked in this manner provides for admitting steam to each end of the cylinders by opening the steam port in proportion to the lead, the same as with the Walschaert valve gear.

If the union link connecting the combination lever to the crosshead should break, disconnect the eccentric rod, also the reach rod connecting to the reverse yoke. Fasten the bottom of the combination lever to the cylinder head or remove it and place the valve centrally on its seat, fastening it securely in that position.

In case the combination lever, union link or crosshead arm breaks, it will be necessary to take down the combination lever and disconnect the valve rod or stem, fastening the valve centrally on its seat. See that all moving parts are either removed or that they are supported or fastened so they will not strike or loosen and do further damage.

If the gear connecting rod should break, disconnect the eccentric rod, then block the bell crank the same as for broken eccentric rod or crank. If the valve rod breaks, clamp the valve centrally on its seat, removing any parts of the gear which are liable to interfere with the engine moving.

DISCONNECTING VALVES AND MAIN RODS

With any type of valve gear, if it becomes necessary to block the main valve centrally to its seat, have the crank pins located so that engine can be started. For this purpose it is best to move the engine until the crank pin on the side not disabled is located slightly back of the top quarter or ahead of the bottom quarter, if the engine is to move forward; or the reverse of this if movement is to be made backward. Shift the valve by hand on the disabled side to accomplish this before blocking. This method may be used should the engine later stop with the crank pin on center so that it is impossible to start.

In case of a broken valve seat, with slide valves, if the break occurs between the steam admission port and the exhaust port, and the loss of steam is such that it is impossible to maintain steam pressure and handle train; if the valve is not damaged disconnect the valve rod, place the valve centrally on its seat, operating the engine on one side. In such cases it may be determined whether the blow can be stopped by placing the valve centrally on its seat by simply placing the crank pin on either the top or bottom quarter and the reverse lever in the center, giving the engine steam. If the seat is broken so badly that steam will blow through in any position of the valve, and the loss of steam is such that the engine cannot be operated without stopping the blow, take up the steam chest cover and plug the live steam ports, placing blocking on top of these plugs and bolting the blocking down solid by bolting the steam chest cover on top of the blocking. Of course, it will be necessary to remove the valve in order to accomplish this. If this cannot be done, disconnect the valve rod and have engine towed in.

In the case of broken bushing, with piston valves, if the blow is so heavy that the engine cannot be operated, place the valve centrally on its seat and if this will stop the blow disconnect the valve rod, fasten the valve securely and proceed. Usually if the bushing is so badly broken that the loss of steam at the exhaust is so heavy that the engine cannot handle its train, the valve or some part of the valve gear is also damaged. If this is the case it is

necessary to disconnect on that side. If steam enters the cylinder after placing the valve centrally on its seat, so that the engine cannot be operated, care must be taken before disconnecting the main rod to determine whether steam enters one or both ends of the cylinder. For this purpose open the throttle slightly with cylinder cocks open and note if steam appears at one or both cylinder cocks. If the steam enters one end of the cylinder only, the crosshead should be blocked at the opposite end of the stroke. Care must be taken to determine whether the front crank pin, side rods, counter-balances, etc., will clear the crosshead, if blocked at the back end of the guides. If necessary to block the crosshead at either end of the guides and it is impossible to prevent steam entering that end of the cylinder, prepare the engine to be towed by disconnecting the valve rod or stem so that the valve will not travel in the broken bushing. Do not attempt to handle the engine under her own steam.

If necessary to disconnect an engine on both sides, so that the engine must be towed in, disconnect only those parts necessary to provide for the engine being moved, remove the indicator plugs to provide lubricating the cylinders if necessary. If it is not necessary to disconnect either valve rods or main rods, the cylinders may be lubricated by disconnecting the oil pipes near the steam chests, or the choke valves may be removed from the oil pipes, and the cylinder lubricated by using the auxiliary oil cups on the lubricator. If steam can be passed through the oil pipes in the usual manner, the cylinders may be lubricated by operating the lubricator.

In each case where the valve rod is disconnected and the valve is placed centrally on its seat, it should be securely fastened in that position. If the main rod is not taken down the indicator plugs should be removed to provide for lubricating the cylinder and relieving compression.

The indicator plugs are located at each end on the side of cylinders. There are also peep hole plugs in the side of the valve chambers on all piston valve engines, which open into the steam ports leading to the cylinders. In the case of compound engines these peep hole plugs lead into the steam ports to the high pressure cylinders. On balanced compound engines the starting valve pipes are connected at this point. Removing the peep hole plugs will therefore provide for relieving compression in the cylinders, and for compound engines will take care of the high pressure cylinders.

BLOCKING MAIN VALVE ON CENTER

To hold the valve centrally on its seat when it is desired to operate the engine on one side, the valve stem may be fastened by loosening the packing gland nuts and prying one side of the gland away from its bearing, then apply a small wedge on that side behind the gland and tighten the nuts on the opposite side. The balance of the nuts should be drawn up tight enough to prevent their working off. Be careful not to cramp the gland so tight on the valve stem that it will be cracked or broken. If the valve steam is fitted into a crosshead and the stem is not broken, block the crosshead to hold the valve. Some engines are equipped with

clamps for clamping the valve stem and in some cases a set screw is provided in the crosshead guide for this purpose. The valve may be held by blocking the valve rod, using wedges between the valve rod and frame or any nearby castings or other parts if the valve rod and valve stem are connected after disconnecting other parts.

BLOCKING CROSSHEAD AND CRANK PINS

Do not neglect in any case, when the main rod is disconnected, to firmly block the crosshead at the front of its guides, unless conditions make this impossible. Steam may leak into the cylinder, and if the crosshead is not firmly blocked, the piston may be moved, resulting in considerable damage. Remove the indicator plugs at the front end of the cylinder or take out the front cylinder cock. If the crosshead is blocked at the back end of guides, take out the cylinder cock or indicator plug at that end of cylinder and make sure that front crank pin will not strike crosshead.

In any case where the main rod is taken down and side rods remain in place, see that blocks provided for that purpose are clamped on the main pin to hold the side rod in place.

The engine may be put in safe running order with a broken valve yoke or stem by blocking the valve centrally on its seat and disconnecting the valve stem. It may be necessary to remove the steam chest cover or the valve chamber head in order to block the valve.

In the case of a cracked slide valve steam chest, slack off on the steam chest studs and wedge between the wall of the steam chest and studs to force the cracked sides together, then tighten down on the cap studs.

If a steam chest is broken so that it cannot be wedged in place sufficiently, block the same as explained for a broken valve seat for slide valves.

If the valve rod, rocker arm or pin, or the link block or pin should break, remove the broken parts so they will not interfere with the motion of the link, and block the valve centrally on its seat, clamping the valve rod or stem to hold the valve in position.

In case a top or bottom rocker arm is broken, place the valve centrally on its seat, remove broken parts which will interfere when the engine is moving, and proceed.

If a valve chamber head of a piston valve engine is cracked, the loss of steam may be considerably lessened by chaining around the valve chamber and wedging tightly between the chain and valve chamber head to hold the damaged parts together, or use a small jack in place of wedges under the chain.

When an engine is reversed air pressure in the cylinders is forced into the valve chambers and steam pipes up to the throttle valve. The piston in the cylinder will draw air into the cylinder through the cylinder cocks and exhaust and on its return stroke will compress this air, driving it through the valve chamber. Consequently, if an engine is moving at a good speed and the valve motion is reversed, the cylinders will build up a heavy pressure in the steam chests and valve chambers, and unless the throttle is opened, may create a sufficient pressure to damage the steam chest

or connections leading back to the boiler. At high speeds some of these parts are usually damaged unless the throttle is open.

When for any reason, any part of the valve gear is disconnected so that the valve motion on both sides of the engine cannot be reversed together, no attempt should be made to reveres the engine without first stopping and changing the blocking on the disabled side, so that both sides of the engine will work in unison.

KEYING UP MAIN AND SIDE RODS

When keying up the back end of the main rod, place the crank pin on the lower back eighth. Usually the main rod brasses are so fitted that they may be keyed up brass to brass without danger of being too tight on the crank pin. In any case, when keying up rod brasses, it should be determined that the brass has not been keyed up too tight, by moving the rod from side to side on its crank pin.

In keying up the brass at the front end of the main rod, the crank pin should be placed on the bottom quarter.

In keying up side rods, the crank pin should be placed on the front or back center, in order that during the process of keying up the rods, the proper length of rods will be maintained. If the crank pins are near the top or bottom quarter when the side rods are keyed up, the rods may be keyed to an improper length, so that as the crank pins pass the center there will be a tendency to force the driving wheels against their bearings. This would set up damaging stresses throughout the rods, crank pins, driving axles and frames.

In case a side rod key is lost, endeavor to fill up the key-way with a piece of iron of any suitable size, or if possible, wedge several pieces into the key-way. A number of brake shoe keys, removed from a car or the tender may be used, driving them down firmly and if possible bending them over at the bottom to prevent their coming out. The brake on the tender or car from which the brake shoe keys were removed, should have the brake shoes removed and the brake cut out.

If front cylinder head is broken, disconnect the valve rod, place the valve central on its seat and proceed.

In case of broken guide bolts, if other parts are not broken or distorted, see if a bolt can be secured from some part of the engine or a car to use temporarily to get engine to terminal.

If a guide block is broken, or the guides are broken or badly sprung, if the crosshead is broken, or the guide yoke is broken, take down the main rod, also disconnect the valve rod and place the valve centrally on its seat. If the crosshead can be moved to the other end of its guides, it should be blocked at one end of the stroke, preferably the front end. If the crosshead cannot be blocked at either end of the stroke, it should be blocked securely on both sides of the crosshead to hold it in whatever position it happens to be. When blocking the crosshead in its guides on any engine, see that the front crank pin will clear the crosshead.

BROKEN SPRINGS, HANGERS AND EQUALIZERS

In the case of a broken cross equalizer in front of the front driving boxes, if the engine is equipped with a two wheel truck in front, which is connected to a long equalizer reaching under the saddles, raise the engine as high as possible by running the engine truck wheels upon a wedge, then block between the top of the front driving boxes and the main frame, see that the main frame clears the engine truck frames to provide for the proper curving of the truck, also that the lowest part of the driving brake gear is high enough to clear rails, switches, etc. Raise the back end of the long equalizer if necessary and block it up to clear rails, etc.

If the long equalizer connecting to the front truck and leading back under the cylinder saddles breaks, raise the engine as high as possible by running the engine truck wheels upon a wedge, placing a metal block between the top of the front driving boxes and the frame, block between the back edge of the cylinder saddles and the top of the long equalizer, if the break occurs between the saddles and engine truck. Then remove the wedges. If the engine is high enough so that the main frame clears the engine truck frame and the driving brake parts are high enough to clear the rails, frogs and switches, the engine may proceed. If it is necessary to raise the engine higher, place the wedges under the front driving wheels, raise the engine as high as possible through this means, block between the top of the engine truck and the main frames or deck casting; remove the wedges and run the engine truck wheels on the wedges again, placing additional blocking between the back edges of the cylinder saddles and the long equalizers, then remove the wedges. It might be necessary to place blocks between the top of the driving box and the frame at the second pair of drivers, then running that pair of wheels upon the wedges and blocking between the top of the front driving boxes and the frames, in order to support the engine high enough in front to clear the engine truck and provide for curving. Run slow enough when blocked up in this manner to prevent overheating bearings or damaging main frames or journals.

If the long equalizer breaks behind the cylinder saddles, raise the engine in front by raising the truck wheels upon a wedge and blocking between the top of the front driving boxes and the frames. This method should be used in case the hanger at back end of the long equalizer breaks.

In the case of broken driving springs, block the equalizers each side of the broken spring so as to hold them in as nearly their normal position as possible, removing or fastening the broken spring if necessary before proceeding.

In the case of a broken driving spring equalizer proceed the same as for a broken spring hanger or spring, blocking all parts closest the break in as near their normal position as possible.

In the case of a broken driving spring or hanger or broken driving spring equalizer, or engine truck equalizer which connects the driving springs to the engine truck; note if all spring hangers and other parts are tight and in their supports, so there is no

danger of any of the parts falling out of place while the engine is moving. If necessary secure the broken parts so that they will remain in position. If no parts interfere when the engine is moved a few revolutions the engine may proceed. Before proceeding note whether the lower parts of the driving brake rigging and also any broken parts are high enough to properly pass over rails, switches, etc. Also see that the main frame and other parts clear the engine truck frame in order to provide for the proper curving of the truck. Remember that the weight is not properly equalized on the driving wheels and truck wheels, and there is therefore liability of some bearing overheating. Run slowly when proceeding in this manner so as to prevent badly overheating bearings or damaging main frames, journals or rails, as the weight will be excessive on those wheels required to carry the weight on account of the broken parts. If necessary to raise the engine, place metal blocks between the driving boxes and frame which have the most clearance between the driving boxes and frame, and which are nearest to the broken spring or hanger. Then run the driving wheel upon a wedge to raise the engine frame, raising the engine as high as possible, block the spring equalizers closest to the point of breakage, as nearly to their normal position as possible. If the reverse lever can not be moved, take out the pin connecting the reach rod to the reverse shaft arm, blocking in the top of one link above the link block, and in the bottom of the same link under the link block, setting the link block at a position in the link which will provide for starting or it might be possible to place a bar across the frame, under the reverse shaft arms to hold the links in the desired position. Secure the bar to the frame and also to the reverse shaft arms, so that they will remain in that position.

If an engine truck spring or spring hanger breaks, with a four-wheel truck, raise the truck frame and block between the bottom of truck frame and the equalizers, to hold the truck frame in its normal position.

If a trailer truck equalizer or spring is broken, examine the broken parts to determine whether or not they will interfere in any way when the engine is running, and also whether there is liability of any of the parts falling out of place while the engine is moving. If not, proceed; remembering that the weight is not properly distributed on all bearings and that overheating of the truck of driving boxes may occur.

On trailer trucks having outside journals, when a spring or spring hanger or equalizer breaks, the truck will be tilted up on the broken side on account of the weight being relieved. This may cause the truck to be derailed in backing up. In case of breakage of the above parts, raise the engine frame at the rear and block between the trailer radius bar or other part of trailer truck frame and the main frame. A convenient place to do this is at the corner of the truck frame where the radius bar is bolted to truck frame, the blocking to be placed between the truck frame and the bracket or guide bolted to main frame. The guide or bracket loops around the trailer spring seat, and bolts to the main frame at both ends. The object of blocking up as described, is to hold trailer wheel solid on the rail. The back end of the frames may be raised by running the back driving wheel upon a wedge.

When blocking up between the trailer and main frame as described, see that all parts of the trailer truck frame and main frame clear the trailer truck axle. If necessary run the trailer wheels upon a wedge and block on top of the back driving box on the disabled side, then run the wheel off the wedge, jack up the back end of the trailer equalizer and block between the top end of the equalizer and the main frame forward of the fulcrum pin. If the trailer axle clears the main frame sufficiently the engine may then proceed. If necessary to support the engine at other points to insure the frame clearing the axle, run the trailer wheels upon a wedge then block between the top of the draw-bar between the engine and tender and tail brace, as close as possible to the chafing iron. Metal blocks should be used for this purpose and they should be secured so they will not fall out of place. Run the trailer wheels off the wedge. If the main frame clears the axle the engine may then proceed at reduced speed.

BROKEN PISTONS, PISTON RODS AND CRANK PINS

In the case of compound engines, if the piston is broken in the high or low pressure cylinder, the engine may proceed providing the broken pieces will not cause pounding in the cylinder or danger of knocking out the cylinder head or damaging other parts.

If a piston rod is broken on a balanced compound engine, either a high pressure or low pressure, if broken close to the piston head so that the piston rod is long enough that it will not travel out of the piston rod packing, the piston head may be removed from the cylinder, replacing the cylinder head and proceeding.

If either the high pressure or low pressure piston head is broken on a balanced compound engine, and the piston head can be removed from the defective cylinder, the valve may be left connected and the engine may proceed, after removing the broken parts and replacing the cylinder head. If the broken parts cannot be removed to prevent striking, disconnect the valve rod, place the valve centrally on its seat and securely fasten it there. Take down the main rod, secure the crosshead at the front of its guides; if this is impractical secure it at the back end of its guides, noting that the front crank pin clears all parts of the crosshead. Remove the indicator plugs or cylinder cocks from the undamaged cylinder to provide for circulation of air and proceed. Wooden blocks which fit in the guides are provided on the engine to block the crosshead in case of break-downs.

If the high pressure or low pressure piston rod on a balanced compound engine is broken close to the crosshead and the cylinder head is broken, disconnect the valve rod, place the valve centrally on its seat and securely fasten it there. Remove the indicator plugs or cylinder cocks from the undamaged cylinder, and the piston packing gland if necessary for the broken piston rod to clear the cylinder parts, and proceed.

If a main crank pin is broken off, all side rods on both sides of the engine and the main rod on the disabled side should be taken down. The crosshead on the disabled side should be properly

blocked at the front of its guides, the valve rod disconnected and the valve placed centrally upon its seat and securely fastened there. The engine should be handled carefully under these conditions as any attempt to move the engine suddenly results in violent slipping of the driving wheels on account of the full power of the cylinder being exerted on only one pair of driving wheels.

BROKEN MAIN AND SIDE RODS

In the case of a broken main rod or strap, take down the broken main rod on the disabled side, place the valve centrally on its seat and securely fasten it there. Securely block the crosshead at the front of the guides and proceed on one side. Wooden blocks are provided on the engine to fit the crank pin when main rod is disconnected, this is in order to hold the side rods in place.

If a side rod breaks, remove the same section of the side rods on the opposite side. In some cases it will be necessary on account of knuckle joints, to remove an additional section besides the broken sections of rods, in which case corresponding rods on the opposite side should also be taken down. When side rods are removed care must be used in handling the throttle valve as slipping of the driving wheels occurs very easily.

BROKEN WHEELS AND AXLES

If an engine truck, trailer, or tender wheel breaks, endeavor to slide that pair of wheels so as to clear the main line, placing a tie or its equivalent in front of the wheels or chain the wheels to keep them from turning if necessary.

If an engine truck, driving axle, trailer or tender axle breaks, it is usually impossible to do anything, except send for help. However, in the case of small engines, if it is a back engine truck axle, the back end of the truck frame may be jacked up and blocking placed between the front end of the truck frame and the main frames. A chain may then be placed around the back end of the truck until the engine can be gotten clear of the main line. If a front engine truck axle is broken, endeavor to raise the front end of the truck high enough to clear, block between the main frames and the back end of the truck frame, chaining the front end of the truck frame to the main frames.

With a broken tender axle on rear end of rear truck, endeavor to raise that end of the truck and chain it over the rear end sill. If it is either of the inside axles, place a tie or rail or other timber if available, across the top of the tender, chaining up each side to support that end of the truck. If this is impractical endeavor to jack up the broken end of the truck frame, so that a tie may be placed under the truck frame on the rail, so that the engine might be moved to a point where the main line will be cleared. If a front axle on the front tender truck breaks, chain the truck frame to the front end sill. It is possible on some of the steel underframe tenders to place a piece of rail or other suitable support between the bottom of the tender and over the plate just above the tender truck, so that the end of such rail or timber will protrude over the tender journal box for chaining up the inside ends of front or back trucks.

With an eight wheel engine, if the back driving tire is broken, run the back wheel with broken tire upon a wedge to raise it clear of the rail, remove the driving box cellar and place a block between the driving spring saddle and the frame at the disabled wheel, also place a block between the driving axle and the binder brace or pedestal to fill the space tightly under the journal having the wheel raised. If, when the wheel is run off the wedge, there is not sufficient clearance to prevent the wheel touching the rail, try again raising the engine and place a tie on the tank and engine deck, chaining around the tie and the back end of the engine frame or tail brace, to support some of the weight of the back end of the engine on the tender. At the same time chain from the back end of the engine frame on the side of the broken tire, to the front end of the tender frame on the opposite side, to hold the flange of the back driving wheel against the rail. Blocking on top of the main driving box on the disabled side and the back driving box on the opposite side will help to support the rear end of the engine and may avoid the necessity for carrying any weight on the tender deck. Blocking may be used between the end sill on the tender and the engine deck at the outside end of end sill on the opposite side from damaged wheel, to prevent that side of engine moving over and causing derailment. Chain or fasten the blocking so it will not fall out of place.

If other than the back tire of an eight wheel engine is broken, run that wheel upon a wedge, remove the driving box cellar and block solidly between the spring saddle and main frame over the wheel with broken tire, also block solidly between the driving axle and the pedestal or binder brace so that the wheel will be held clear of the rail when the wedge is removed. If the broken tire comes off the wheel and the distance to clear the main line is not far, the engine may be moved to clear by running on the wheel center. If other trains will not be delayed block up at once. It may be necessary in the case of the back tire on other than eight wheel engines, to block on top of the driving box at the next pair of wheels, using a metal block between the top of the box and the frame to help support the back end of the engine to keep the back wheels clear of the rails after blocking them up.

If a driving axle breaks between the frames it may be possible to handle the engine carefully for a sufficient distance to clear the main line without the necessity for blocking up in any manner. This applies to broken crank axles. If the driving wheels stand approximately in their normal position this may be attempted, being careful not to slip the driving wheels, and proceeding slowly. If they stand in such a position that the side rods are badly cramped, remove the side rods, moving the engine sufficiently to loosen the side rods if possible, run the wheels at the broken axle upon a wedge, and if necessary jack up the end of the axle between the frames so that the driving box cellars may be removed, place a block solidly between the driving axle and the pedestal brace, chain the bottom of the wheels together tightly, or place a timber or rail through the driving wheel spokes and over the top of the frames to help carry the weight of the wheels. When the wheels are removed from the wedges they should clear the rails.

If the main axle breaks outside the driving box, remove all the side rods and the driving wheel, jack up the broken end to normal position, remove the driving box cellar and block solidly between the axle and the pedestal brace; also block solidly between the spring saddle and the frame at the point where the axle is broken.

When locomotives are being prepared for towing on account of being disabled, the engineer must consider the necessity for cutting out the driver, tender or trailer brakes. If there are no defects which would make it unsafe to operate the brakes they must be left cut in and working.

Locomotives handled dead in trains with side rods in position are not to be run faster than 20 miles per hour.

Locomotives with side rods all removed, and all drivers are on the rail, may be handled at a speed of fifteen miles per hour or one mile in four minutes.

Where tire is broken, or an axle is broken, necessitating the swinging of one or more pair of wheels, the speed should not exceed one mile in six minutes.

When wheels are blocked up to clear the rail, the weight formerly carried by such wheels must be transferred to other wheels. This causes the weight to be excessive on the wheels which are required to carry the additional weight, making the weight excessive beyond a safe limit for high speeds.

In all cases of break-downs where blocking or chains are used to support the weight in place of springs or hangers, or if the wheels are blocked up, the engine should be moved slowly and carefully to avoid derailment, particularly in case chains or blocking should fail. The speed should be kept very low and care used in passing over frogs and switches to prevent derailment at such points.

After jacking up a locomotive or running wheels up on wedges for the purpose of blocking up, see that the waste under the engine truck or trailer journals, and that driving box grease cellars are properly adjusted, or if oil cellars are used for the driving boxes, see that the waste is properly adjusted. If the engine has been off the truck, inspect all the cellars under the engine to see that cellar bolts have not been broken or that the waste has been pushed down so as to clear the journals, making such adjustments as are found necessary. The plates in grease cellars may be pushed down and distorted or stick under these conditions. These precautions are necessary to guard against hot boxes due to the weight of axles and wheels being sometimes carried on the cellars during rerailing engine after derailment.

BREAK-DOWNS—MALLET TYPE COMPOUND

In the case of a broken unit pin or oscillating casting, if there is danger of the low pressure frame pulling too far away, allowing the boiler to drop off the sliding bearings, disconnect the low pressure steam pipe to prevent any steam reaching the low pressure cylinders. If backing up, chain the low pressure frame to the unit pin connection, or around the high pressure cylinders.

With a broken low pressure valve stem or piston, disconnect the broken parts, place the valve centrally on its seat and secure it in that position. Proceed with as much of train as the engine will handle. Under these conditions the engine should be worked as light as possible, as only one low pressure valve must take care of the exhaust from both high pressure cylinders. In case of a broken high pressure valve stem or piston, take down the main rod, place and secure the valve centrally on its seat and proceed. The low pressure engine at this time will receive steam from only one high pressure cylinder, the power of the engine will therefore be impaired. The starting valve should be used continuously under these conditions, and an attempt made to handle the full train. It may be possible in some cases of a broken valve stem to leave the high pressure main rod in position, but under these conditions steam from the low pressure steam pipe enters both ends of the high pressure cylinder, which may produce back pressure sufficient to greatly reduce the work which the engine might perform with the main rod disconnected.

If the main throttle of a Mallet is disconnected closed, the starting valve may be used to move the engine at very low speed.

POUNDS

If the piston head is loose on the piston rod, or the follower plate bolts are loose, if the piston rod is loose in the crosshead, or the main rod is too long or too short, or the wrist pin is loose in the crosshead, if the rod brasses are loose on crank pins or not properly keyed, if the pedestal brace or binder is loose, or the driving axle worn out of round, or if the crosshead is loose in its guides, or knuckle pins or their bushings in side rods worn; pounds will occur when the engine is working.

The follower head loose or the main rod too long or too short will pound most when the engine is drifting with the throttle closed, because the weight of the moving parts will take up all the slack in the connections and may cause the piston to strike the cylinder head. If the main rod is too short the piston will strike the back cylinder head. If the main rod is too long the piston will strike the front cylinder head. If a pound occurs when the throttle is closed in drifting, open the throttle and work sufficient steam to cushion the moving parts until a stop is made.

The piston rod loose in the crosshead will pound the hardest when the engine is working steam. The piston rod is taper fitted at the piston head and also has a taper fit into the crosshead. When steam is admitted behind the piston head it tends to pull the piston rod out of the crosshead and drive the piston head off its rod, while on the other hand, if steam is admitted in front of the piston, the piston head is driven back on the taper fit and the piston rod is driven into the taper fit in the crosshead. The heaviest pound would therefore take place when the piston was being driven forward in its cylinder.

When there is lost motion between the driving box and shoes it allows the driving box to move back and forth when power is applied at the crank pin, causing very heavy pounding to take place, and to determine how much lost motion exists, the crank pin

should be placed on the top or bottom quarter on the side being inspected, have the fireman open the throttle a very little and move the reverse lever from the forward to the backward position several times, noting the movement of the driving box at this time Care should be taken not to let the engine move so that the crank pin will be moved from its position on the quarter. The driving brakes should not be applied at this time, they should, however, be operative, so that the engine may be stopped promptly in case it starts to move. Sometimes it is difficult to reverse an engine with the throttle open, try opening the cylinder cocks to assist in such cases. It might be possible that a heavy pound will be noticed that is not caused by improper adjustment of the wedge. Such pounds may occur on account of a loose or broken binder or pedestal brace, or the driving shoe or wedge may be improperly lined, that is, it may be tight at the top or bottom and loose at the other end. The journal or driving box brass may be badly worn or broken. If the driving box wedge has been moved up as far as it will go, or until it strikes the frame and still the box pounds, the wedge should be reported for relining.

The same method of placing the crank pin on the quarter and reversing the engine under a light throttle should be used to locate pounds in the main or side rods.

MAIN THROTTLE VALVE LEAKING

If, when the throttle is closed, steam shows at cylinder cocks, it may be caused by a leaky throttle or a leaky dry pipe, or steam entering the steam chest from the lubricator. To determine where the leak exists, close the steam valves to the lubricator, shut off the air pump, fill boiler with water so that water will rise in boiler high enough to cover dry pipe, open the cylinder cocks. If dry steam shows at cylinder cocks under these conditions the throttle is leaking. If both steam and water show at cylinder cocks it would indicate dry pipe leaking. If shutting off the lubricator stops the flow of steam at the cylinder cocks, it would indicate too much steam getting through the lubricator choke plugs. Do not confuse a show of steam at the cylinder cocks with the air pump exhaust. The air pump exhaust being tapped into the cylinder saddles will some times cause steam to show at the cylinder cocks when they are open.

If the main throttle becomes disconnected and the throttle valve is closed, prepare the engine to be towed to terminal, or to some point where repairs can be made. If the engine was located at a point where relief was not available, and facilities were at hand the boiler may be filled up well with water, the steam blown off, allowing the boiler to cool down, the dome cap removed and the throttle connected up.

If the throttle becomes disconnected open, it requires great care in order to handle the engine. The steam pressure should be reduced low enough so that the engine may be handled with the reverse lever and brakes.

LOCATING BLOWS IN VALVES AND CYLINDERS

If anything occurs which would allow live steam to pass by the ends of a piston valve to the exhaust port, or by the face of a slide valve to the same port, there would be a constant blow at the exhaust. On the other hand, if the valve is tight and the steam piston allows the steam to pass from one end of the cylinder to the other, a blow will occur only while steam is being admitted to either end of the cylinder.

Fig. 32 is a sectional view of the balanced compound engine, in which it will be seen that the main valve is really three small spools, all fastened together and attached to the valve stem. This valve being equipped with twelve packing rings, numbered 1 to 12, the arrows indicate the course of the steam passing through the valve chambers and cylinders. Steam is being admitted to the back end of the high pressure cylinder. If the starting valve was open live steam would therefore pass through the starting valve to the front end of the high pressure cylinder, thence following the course of the arrows into the low pressure cylinder. Rings, 1, 2, 3, 4, 9, 10, 11, and 12 now separate the valve chamber from the exhaust cavity. Rings, 3, 4, 9, and 10 have nothing to do with the distribution of steam, but merely prevent the steam from flowing from the valve chamber to the exhaust cavity. Ring 1, 2, 11, and 12 control the admission from the valve chamber to the low pressure cylinder, and from the low pressure cylinder to the final exhaust. Rings, 5, 6, 7, and 8 control the admission of live steam to the high pressure cylinder and the exhaust from the high pressure cylinder to the valve chamber. It can be seen that with the pistons located near the center of their cylinders, and the low pressure crank pin on bottom quarter, placing the reverse lever in the forward center would move the valve to the position shown in Fig. 32.

If rings 1, 2, 11, or 12 are leaking badly or broken, leakage will occur from the valve chamber to the final exhaust. This will cause a reduction of pressure in the low pressure cylinder, at the same time causing a blow at the stack and a consequent weakening of the exhaust through that end of the low pressure cylinder. If rings 3, 4, 9, and 10 leak that would tend to cause a constant leak from the valve chamber and a blow at the exhaust each time steam was exhausted from the high pressure cylinder to the valve chamber. This would cause a reduction of steam pressure in the valve chamber and reduce the pressure admitted to both ends of the low pressure cylinder, tending to weaken the exhaust at both ends, if the engine was standing in the position shown in the cut, and the starting valve open, opening the throttle would cause a continuous blow at the stack when the throttle was open.

If rings, 5, 6, 7, and 8 are leaking leave steam would be admitted into the valve chamber, causing the pressure to build up higher than normal, which would increase the amount of steam being admitted to the low pressure cylinder, causing the exhaust from both ends of the low pressure cylinder to be heavier than normal.

To test for a valve blow with the balanced type compound, place the crank pin on either the top or bottom quarter and the reverse lever on the center, open cylinder cocks to the high pressure cylinder. Steam should not show at either cylinder cock when the throttle is opened.

If the high pressure cylinder packing is blowing, live steam would pass by the high pressure piston to the blow pressure cylinder, causing more steam to be admitted than under normal conditions, which would cause the exhausts on that side to be heavier than normal, if the low pressure cylinder packing rings were leaking, steam from the high pressure cylinder would pass by the low pressure piston, causing a blow at the stack.

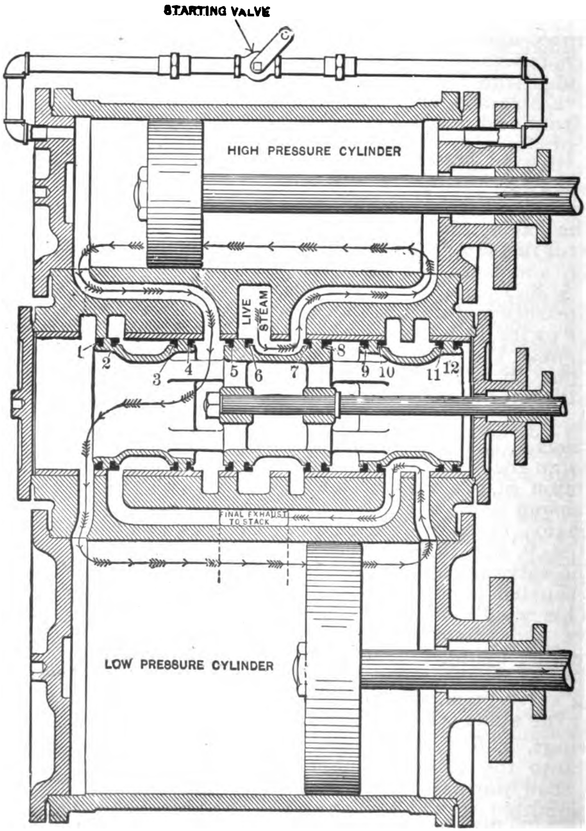


FIG. 32.

To test for a blow in the high pressure cylinder of a balanced compound engine, place the low pressure crank pin on the bottom quarter, reverse lever in forward gear, open cylinder cocks, close the starting valve, apply the brakes and open the throttle. Now pry open the front high pressure cylinder cock with a round bar or other means to determine if steam blows through the front end of the cylinder. If there is no blow by the piston, little or no steam will show at the front cylinder cock.

To test the low pressure cylinder packing leave the crank pin in the same position, move reverse lever to back gear, open the starting valve, close the high pressure cylinder cocks, open the throttle. Now pry open the front low pressure cylinder cock. If little or no steam shows at this cylinder cock it indicates that there is no steam passing by the low pressure piston.

The object of placing the crank pin in a position to admit steam to the back end of the cylinder in testing cylinder packing is to determine if the follower plate is leaking at the same time that test is made for packing leaking.

To test for blows in valves with simple engine, place crank pin on top or bottom quarter, reverse lever in center, apply brakes, open cylinder cocks and then open throttle. If steam appears at cylinder cocks the valve or rings are leaking.

To test for blows in cylinder packing, with simple engine, place crank pin on top quarter, reverse lever in full forward gear, apply brakes. Now pry open front cylinder cock with a round bar or other means to determine if steam blows through to the front end of the cylinder. If there is no blow by the piston, little or no steam will show at the front cylinder cock.

The exhaust rings in a piston valve will cause blows to occur as the exhaust ring is moving back and forth over the bridges between the steam and exhaust ports. They are difficult to locate when the engine is standing unless the valve is moved to certain positions off center or off its central position on the seat. When the crank pin is on the top or bottom quarter and the valve is placed in its central position, the admission rings prevent steam entering the cylinders. Moving the reverse lever slightly toward either end of its quadrant moves the valve away from its central position and places the exhaust ring on the bridge between the admission and exhaust ports. A blow may occur at the stack at this time and steam show only at one cylinder cock. This would indicate that the valve was causing the blow at the stack and not the cylinder packing.

With balanced slide valves, if the strips are leaking, either where they seat against the balance plate or in the grooves cut in the valve body, or if the strips leak where they join at their ends, steam will be admitted to the top face of the valve, since there is a hole through the top of the valve connected to the exhaust a blow will occur at the stack, with the valve in any position on its seat. With the valve in its central position on the seat no steam may show at the cylinder cocks when this blow occurs. On the other hand, opening the cylinder cocks may show that air is being drawn into the cylinder. If the engine is equipped with channel cocks, located underneath the saddles and connected to the exhaust channels leading to the nozzle, opening the channel

cocks will show on which side the valve is blowing to the exhaust.

Some times steam may be admitted to one end of a cylinder which will cause a blow at both cylinder cocks and at the stack, while admitting steam to the other end of the cylinder will show steam only at the cylinder cock on that end, with no blow at the stack. This might be caused by the follower plate on the piston being loose, and when the steam is admitted to one end of the cylinder the follower plate is blown loose from its joint letting the steam blow by the piston, while when the steam is admitted to that side of the piston on which the follower plate is located, the follower plate is blown tightly to its seat, which, of course, prevents the blow in that direction.

LOCATING BLOWS—MALLET TYPE COMPOUND

In testing for blows in the low pressure valves or cylinder packing, proceed the same as for a simple engine, using the starting valve to admit steam to the low pressure valve chambers. When steam is blowing by the high pressure valves or cylinder packing it will be noticeable by the low pressure engine working very strong or slipping excessively both in starting and running, also, when the main throttle is open with the engine standing, steam will show immediately at the low pressure cylinder cocks. To test the high pressure valves proceed the same as for a simple engine, except that after the valve has been placed centrally on its seat on the side to be tested, disconnect the valve on the opposite side and place it centrally on its seat. This provides for testing the valve on the side to be tested and at the same time the valve which is disconnected on the opposite side. To test the high pressure cylinder packing after determining if the high pressure valves are tight, proceed the same as for testing the high pressure valves with the exception that the valves should be moved to admit steam into each cylinder alternately. The object in disconnecting the valve on the opposite side from the one being tested, is to prevent steam entering the receiver from that side, and as the valves have inside clearance such steam would show at cylinder cocks on the side where tests are being made.

HOT BEARINGS

Two surfaces in contact under motion create friction, which develops heat. The introduction of a lubricant, such as oil, between such surfaces keeps the surfaces separated and reduces the tendency for heating to occur; therefore, in the case of hot bearings of any nature it should be determined if the surfaces are overheating merely due to lack of lubrication, or whether it is because the two surfaces are drawn together so tightly that it is impossible to get lubrication between them. If the parts are arranged so that there is some clearance which does not cause the two surfaces to be bound together it is only necessary to introduce proper lubrication to overcome the heating, unless the surfaces are badly cut. It might be possible, in the case of eccentric straps or guides to loosen the bolts holding such parts together, to provide sufficient clearance, applying shims or liners to keep them separated,

and tighten the bolts securely. In the case of rod brasses heating, if keys are provided, they should be slacked off if it is found that the brass fits the pin tightly. Remember that when heating takes place, the various parts expand, which may be responsible for the parts being found excessively tight when hot bearings occur.

In case of hot journals, such as driving boxes, engine trucks or trailers, determine if the journal inside the frames shows the same or greater heat than the outside of the hub. If the wheel hub and end of axle is considerably hotter than the axle inside the frames close to the box, and there is not much indication of heat in the box itself, it is evident that the heat is being generated in the wheel hub. If allowed to continue this may also cause sufficient heat throughout the journal to burn the oil and cause the box to run hot, unless the hub receives sufficient lubrication to prevent this. Examine for lateral motion at both wheels, to determine if there is any clearance between the wheel hub and the box on either side. If the boxes fit closely against the hubs on both sides continued care will have to be given the hubs on both wheels. When oiling the hub under these conditions, the box should also be thoroughly oiled. Examine to see if the cellar is properly in place, the box should be inspected at every opportunity to determine whether or not the heat is increasing or decreasing. If it is found that the heat increases, and the packing burns or smokes, the cellar should be repacked at once, that is, the engine should be run no great distance after discovering this condition. If possible pick out a place to stop where the train can be started readily.

When a bearing is discovered to be unusually hot, that is, the metal is at a very high temperature or nearly red hot, care should be taken not to cool the bearing suddenly. The temperature should be reduced sufficiently, or to a point where engine oil will not flash or burn. The cellar should then be repacked in order to remove the burned waste from the journal.

Where hot bearings occur and there is liability of causing excessive delay to a train, it should first be learned whether another engine is readily available to take the train. Where the conditions are such that a reduction in speed will enable the train to reach its terminal, or some point where relief might be had, without incurring any greater delay than would be caused by waiting for relief, such relief should not be asked for. This is particularly true on freight trains, or any train which does not require high rates of speed.

Ordinarily, journals, or other bearings lubricated with what is commonly called pin grease, or cellar grease, run considerably warmer than bearings lubricated with oil, and this must be taken into consideration when inspecting the various bearings throughout the locomotive. If a bearing, lubricated with pin grease, or cellar grease, gets excessively hot, it should be known that the bearing is receiving proper lubrication. If necessary refill the cups or cellars to provide for this. In the case of driving boxes it should be known that the driving box wedge is not stuck. If it is impossible to repack grease cellars oil the hub side of the driving box liberally with valve oil, and also apply valve oil to the cellar from the inside, if possible. Where difficulty is experienced in packing

grease cellars, on account of not being able to remove the filling plate, or drop the cellar sufficiently to provide for filling, it may be necessary to block between the binder brace and the bottom of the driving box, remove the cellar bolt on the inside, spot the engine if necessary to get eccentrics, crank discs or counter-weights located so that they will be in their upper-most position, running the driving wheel upon a wedge to raise the journal and driving box so that the inside of the cellar will drop sufficiently to enable the filling plate to be removed. Place a bolt, rod or anything convenient in the loops in the indicators, and pull down on same to pull the plate to the bottom of the cellar, so that the grease may be placed on top of the plate to provide for its feeding. After the cellar is filled, replace the filling plate, run the engine off the wedge and remove the block between the driving box and binder.

When trouble is experienced with hot driving boxes which are lubricated with grease, note the indicator wire which is fastened to the bottom of the cellar. If the loop in the wire is up close to or against the bottom of the cellar, the cellar is empty. If the indicator shows that there is ample grease in the cellar, make sure that they are registering properly by pulling down on the indicators to see if the plate to which they are attached is free in the cellar.

GENERAL INSTRUCTIONS FOR ENGINEERS AND FIREMEN

On reporting for duty at terminals, after complying with rules relative to registering, the engineer and fireman must examine work reports to determine what work has previously been reported on the engine that they are to take charge of. On arrival at the engine determine if the engine is properly equipped with the necessary supplies, in the way of lubricating oils, coal and water, sand and proper tools; also signal equipment such as lights, fusees, flags and torpedoes. Know also that the proper firing tools are on the engine and that they are in good condition. Observe the condition of the various gauges for registering steam and air pressures, see that all lights are in good condition and operative. It is very important that the engineer and fireman should know positively that the water glass is registering correctly, and in order to insure this the water glass should be blown out each trip when taking charge of an engine, and the gauge cocks should be tried to know that they are in good working order. In blowing out the water glass see that the water glass guard is in place, close the top and bottom water glass cocks, open the drain cock and note if both water glass cocks are tight, in case it is necessary to apply a water glass at any time. Then open the bottom water glass cock and blow it out thoroughly, then close it. Then open the top water glass cock and thoroughly blow it out, then close the drain cock and open the bottom water glass cock, see that the water rises promptly in the glass. In case water does not register properly on closing the drain cock, have the water glass cocks examined to determine the trouble. In opening the water glass cocks see that they are open sufficiently to insure proper communication through both the top and bottom water glass cocks. Also

try the gauge cocks to see that they are operating properly and that they register the water level in the boiler in accordance with that shown by the water glass. These trials should be made before the engine is moved. Give the engine a thorough inspection, covering the entire locomotive and tender.

When water glasses are in proper condition to correctly register the water in the boiler, the water in the glass is never entirely at rest while under pressure. When steam is being used from the boiler, circulation is established, which causes the water to increase its agitation in the glass and when the engine is moving, the motion of the boiler is transferred to the water, which adds to the agitation caused by circulation due to the generation of steam. Thus, when an engine is standing and no steam is being used from the boiler, the water in the water glass will appear comparatively calm. However, when the throttle is opened, circulation is established throughout the boiler and the water tends to rise. If for any reason foaming of the water occurs, this causes the water throughout the boiler to raise higher than would be the case if no foaming took place, which shows a corresponding increase in the height of water as registered by the water glass. In order to lessen the disturbance of water as registered by the water glass and gauge cocks, due to agitation of water within the boiler, a water column is applied on certain engines where the application of such a device is considered desirable. Fig. 33 shows the above mentioned water column. Attached to this water column are three standard gauge cocks and one water glass. On the opposite side of the boiler head a standard water glass is applied directly to the boiler. The two water glasses forming a double check on the height of water over the crown sheet, and also broadening the view from different parts of the cab. When taking charge of an engine the gauge cocks should be opened to know that they are in good working order, and that they register the water level in the boiler as indicated by both water glasses. The water glass on the water column, and the water glass on the left side of the boiler head, should be thoroughly blown out, as described in the preceding paragraph. The water column should also be thoroughly blown out by opening the drain cock located below the column.

If necessary to apply a water glass on the road see that all particles of the broken glass and the old gaskets are cleaned out of the water glass cocks and nuts. Apply the new glass so it will not rest in the bottom of the bottom water glass cock, it should clear so that the glass may turn if necessary when tightening the nuts. After the glass is applied place the guard on the water glass, then open the bottom cock and allow the glass to fill with water, after which open the drain cock, the top cock should then be opened and the drain cock closed, see that the water rises promptly in the water glass. Never open the drain cock to blow out the water glass without having the water glass guard in place.

WHEN THE BOTTOM WATER GLASS COCK IS OPEN, IF THE TOP COCK IS NOT OPENED PROPERLY THE WATER WILL BE FORCED UP INTO THE GLASS AND REGISTER A FULL GLASS OF WATER EVEN THOUGH THE WATER IS ONLY AT THE HEIGHT OF THE BOTTOM WATER GLASS COCK. AFTER BOTH WATER GLASS COCKS ARE OPENED, THE WATER SHOULD BE BLOWN OUT TO MAKE SURE THAT IT IS REGISTERING CORRECTLY. DO NOT FAIL TO HAVE BOTH WATER GLASS COCKS PROPERLY OPEN AT ALL TIMES, OTHERWISE THE WATER GLASS MAY INDICATE A FULL GLASS OF WATER AND IT IS VITALLY IMPORTANT THAT BOTH THE TOP AND BOTTOM COCKS ARE OPEN PROPERLY, TO REGISTER THE EXACT AMOUNT OF WATER IN BOILER.

One of the first duties of the fireman on arrival at the locomotive is to examine the grate levers and see that they are in place and properly secured, and that grates are level, also see that ash pan has been properly cleaned and that dumps or slides are closed and properly secured. It is also his duty to inform the engineer upon arrival at the terminal, of any defects that may have developed during the trip which should be reported without fail. When necessary to clean the ash pan on the road do not neglect to wet down the ashes removed to reduce the hazard of fires, also level down the ashes so that pilots of other engines will not strike the pile and scatter fine ashes over the bearing surfaces underneath the engine. This is important, particularly at points where other trains do not stop or where engines pass such points at considerable speeds.

Oil all surfaces needing lubrication, avoid spilling oil out of oil cups and oil holes. This not only wastes oil but contributes to the collection of dust and dirt and the general appearance of the engine. Examine the grates and ash pan, and know that they are in good condition, also the firebox and flues. Try both injectors to know that they are operating properly.

When taking charge of an engine upon which any repairs have been made, inspect all visible parts to note the nature of repairs made, and whether completed. If any bearings have been worked upon see that they receive proper lubrication; also if any new wheels have been applied, or truck brasses, see that the journal boxes or cellars are properly packed. If new packing rings are applied to cylinders or valves, or slide valves have been faced, see that they receive lubrication, particularly in beginning the trip.

It is the engineer's duty to supervise or direct the fireman in his work upon the engine, call his attention to improper practices which he notes and endeavor to give him all the information possible in line with his duties. The engineer must also familiarize himself with the locomotive and its appliances, in order that he might obtain the proper operation from them while on the road and be able to report intelligently any necessary repairs.

Note the water level in the boiler frequently, know at all times how much water you have in the boiler, opening the gauge cocks frequently to check against the water shown by the water glass,

and on approaching the summit of grades, know positively that there is sufficient water in the boiler to permit of closing the throttle after passing the summit. If there is any doubt as to the height of water in the boiler, ease off on the throttle and try gauge cocks to make sure. Observe the steam gauge frequently to keep yourself advised of the steaming qualities of the engine.

When starting a train from state of rest insure that the engine will develop its full power by putting the reverse lever in full gear. Open the cylinder cocks, see that the rails are properly sanded, use no more throttle opening than that necessary to gradually start the train. After the train has been started it should be observed that the entire train is intact, and that nothing has happened to cause the train to part. With compound engines see that the starting valve is in open position. In handling light engines, in the absence of a conductor or pilot, the engineman and fireman should be governed by Operating Department Rules. In starting avoid jerking trains suddenly. In passenger service this is very annoying, as the heavy cars of today cause very disagreeable and damaging shocks. With freight trains such handling may cause damage to the lading or equipment and it is important that the start be made as gradually as possible.

In handling compound locomotives of the Mallet type, the starting valve is seldom used in starting a train. There are times, however, when all the available power of the engine is required to make a start. To avoid making a lunge at the train and possibly result in damage to equipment, the starting valve should be opened and allow the live steam in the low pressure engine alone to take the slack out of the train. After this is done then open the main throttle gradually. This permits better control of the steam and a smoother start than if the main throttle were opened first. By allowing the main throttle to open last, the control of the steam to the low pressure engine is more uniform. The action is similar to starting a train with a double header in which case the engineer on the second engine should allow the head engine to take all the slack possible out of the train before the second engine is given any steam.

The throttle valve is located near the top of the steam dome in order to remove it as far as possible from the water level in the boiler, so that the driest steam possible to obtain from the boiler will be passed to the cylinders.

Do not put so much water in the boiler when the engine is not working that priming or foaming will occur when the throttle is opened. This is particularly important when starting. When drifting on descending grades and approaching an ascending grade, the conditions should be such at this time that the engine may be worked to full capacity and at a good speed approaching the ascending grade. When drifting the reverse lever should be moved toward full stroke sufficiently to prevent pounding of rods, using sufficient throttle opening to provide for drifting. With compound engines open the starting valve while drifting. Care should be exercised in moving the reverse lever toward full stroke when getting ready to drift, particularly at high speeds, in order to prevent the reverse lever moving suddenly to the end of its quadrant. At very high speeds the reverse lever is some times difficult

to control and this fact should be borne in mind. The ability to handle the reverse lever in hooking the engine up at high speeds will determine the ability to handle the reverse lever in dropping it down. Remember that the reverse lever is many times much more difficult to control after it is dropped below half stroke at very high speeds than is the case when it is working near the center; and if the lever is difficult to control at very high speeds, continue to work steam until the speed has been reduced considerably before dropping the lever down and easing off on the throttle to provide for drifting.

Inspect engine thoroughly at every opportunity. Remember that the maintenance of the locomotive as a whole depends largely upon the engineer and fireman in locating conditions which need attention. Do not depend upon anyone else for any condition in which you are concerned. Make it your business to know that any duties devolving on you are performed. Don't neglect to inspect the engine as far as possible at every stop over the division. Inspect bearings at every opportunity, to note their condition. In this way many conditions are found in advance and serious damage may be prevented.

At each stop where an inspection of the engine is made, or where bearings are oiled, note whether the sanders are working and whether sand is properly delivered to rails on both sides. If sand is used as directed, this inspection can be made. When oiling around see that oil holes are open so that bearings actually get lubrication.

Know that the water level in the water glass fluctuates in proportion to the moving of the engine. Where the water in the water glass seems to be almost at a stand-still when the engine is running, determine promptly whether the water glass is registering properly, by blowing out the water glass thoroughly, and trying the gauge cocks. Make sure that both water glass cocks are opened properly.

When foaming in a locomotive boiler occurs, great care is needed in the working of the engine, because water is being carried through the cylinders with the steam. Remember that under these conditions a boiler may be robbed of water very quickly, therefore reduce the use of steam until foaming has been overcome.

Do not leave an engine standing under steam unless the throttle is fastened shut, the reverse lever on the center and the cylinder cocks open. If the engine is equipped with straight air brakes, such brake should be left applied. If a brake cannot be depended upon to hold the engine, and the grade conditions are such that the engine might move, see that the engine is properly blocked. When leaving an engine under these conditions leave the cylinder cocks open and the air pump running. When leaving engines at any time, know that there is sufficient water in the boiler and a proper fire to maintain engine until you return, also in freezing weather, see that injectors have heaters properly applied and that the train line and steam heat line valves are slightly open to provide for circulation at the rear of the tender. When leaving engines at terminals the same procedure should be carried out as in leaving engines at any point, that is, sufficient water and fire should be left

in the engine to protect the boiler until the engine can be taken care of by the roundhouse forces.

If there are any unusual conditions which might interfere with the proper handling of the engine by the roundhouse forces, such as the engine being broken down in any manner, or the air brakes not being operative, the roundhouse forces who handle the engine, should be notified before they take charge.

Take advantage of every opportunity to make the engine perform its work at as short a cut-off and as wide a throttle opening as the conditions will permit; that is, if the engine does its work well with the reverse lever hooked up as far as possible and the throttle wide open, the work should be done in this manner. If necessary to vary from this manner of handling the engine, the above practice should be approached as closely as possible.

On ascending grades with heavy trains, when it is necessary to slow down for any reason, ease the throttle off a sufficient distance from the point of slow down to allow the grade to accomplish the necessary reduction in speed instead of working steam heavily very close to the point of slow down and then shutting the engine off and applying the brakes. This is particularly important when approaching or pulling out of side tracks, stations, etc., so that switches may be opened and closed without the necessity for making complete stops.

Should anything unusual occur that prevents proper firing of the engine it is better to reduce the amount of steam used and allow an opportunity to build up the fire than to continue the heavy use of steam until the steam pressure has been considerably reduced before easing off.

Do not fail to relieve cylinders and valve chambers of condensation at all times, because allowing engines to work water results in more broken cylinder and valve packing rings, cylinder heads, loose piston and damaged piston and valve rod packing, than all other causes combined.

Working water through the cylinders not only reduces the efficiency of the engine, but washes away lubrication on the surfaces of the valve seat and cylinder walls. This increases the difficulty of lubricating these surfaces, and adds to the rapid wear of such parts. When water is carried high enough to effect the conditions in the valve chambers and cylinders, all other devices about the engine which are operated by steam, such as the air pump, coal pushers, headlight generator, etc., will be more or less effected in the same manner as the valve chambers and cylinders. Working water through the cylinders also wets down the front end netting, causing cinders to collect more readily, and sometimes causes the netting to become clogged completely, thereby shutting off the draft, and effecting the steaming of the engine.

The high and low pressure cylinders on a compound engine are so proportioned that if steam is admitted to the high pressure cylinder until the piston travels one half its stroke, enough steam will be exhausted into the low pressure cylinder to build up the desired pressure on the low pressure piston to equal the power exerted on the high pressure piston by the boiler pressure. On the other hand, if steam from the boiler was admitted to the high

pressure cylinder until the piston traveled only one quarter of its stroke, the steam pressure would be lower when exhausted into the low pressure cylinder, and the power exerted by the low pressure piston would be correspondingly lower. In this case the high pressure cylinder would be doing the greater part of the work. It is therefore not advisable to work a compound engine at as short a cut-off as the simple engine. If the speed is too high under a full throttle, when working the reverse lever at the proper cut-off, the throttle should be regulated to produce the desired speed.

To obtain the maximum power of the locomotive the reverse lever must be worked at the proper cut-off for various speeds and loads, and the throttle opening must be regulated in accordance with same.

When the maximum load for the locomotive is being handled, or if the weight of the train is such as will permit, the throttle should be opened fully and the speed regulated by the position of the reverse lever. For economical operation, the reverse lever and throttle positions vary in proportion to the speed and load. For example, if, on approaching an ascending grade, the locomotive is operating at maximum speed under full throttle and the shortest possible cut-off, the speed should not be allowed to change greatly before increasing the cut-off by dropping the reverse lever down. It is the practice at times to allow the locomotive to slow down considerably before changing the reverse lever position and then drop the lever down five or six notches or even more. It is obvious that there is a point throughout the reduction in speed at which the reverse lever should have been moved down one or two notches at a time in order to maintain the maximum power and speed, and prevent the speed reducing in such a short distance. If the grade is uniform and the speed is allowed to reduce considerably before increasing the power of the engine it is impossible to again increase the speed, the time of negotiating the grade is increased and a longer cut-off must be used earlier with a possibility of the speed falling so low that the maximum power cannot be obtained at any position of the reverse lever. This often necessitating "doubling" on account of inability to handle the train over the grade. On the other hand, had the reverse lever been dropped down in proportion to the speed, a higher average speed would have been maintained, the maximum power of the locomotive would have been available and the final speed such that the train would have been handled over the grade successfully.

It is not expected that the exact reverse lever position for all operating conditions can be outlined, the judgment of the engineman is required to take into account the varying conditions of train load, power, speeds, etc. However, to the judgment of the engineman is intrusted the duty of obtaining the maximum service from the locomotive at the greatest possible economy, and for this reason any method that will produce the above results should appeal to the engineman's judgment.

The engineman should be as well versed in the performance of the locomotive at various speeds with different trains working under various throttle openings and reverse lever positions as in other matters effecting train operation. In order to obtain information

in this respect the engineman should note the manner of operating the throttle and reverse lever under the various grade and train conditions, taking into account the fuel consumption in relation to speeds maintained to determine the most economical manner in which the locomotive will produce satisfactory service. The mere fact that a train is handled over a given distance in a certain time does not indicate that the best work has been obtained from the locomotive.

The engineman can, by exercising his judgment intelligently, note the results produced by working the engine at various reverse lever and throttle positions with different trains at varying speeds, and become familiar with the proper cut-offs to use for level and grade work.

As an aid in determining the rate of speed when moving slowly, the table below shows the miles per hour proportionate to the revolutions of the driving wheels. The revolutions of the driving wheels may be counted by watching the crosshead or by counting one for each four exhausts. By such observation the following table will enable the rate of speed to be determined for the various diameter driving wheels:

TABLE OF TRAIN SPEEDS

Diameter of Drivers	79″	73″	69″	63″	57″	
Count Revolutions During	14.1	13.1	12.8	11.2	10.2	seconds

Number of revolutions counted in number of seconds shown above, equals speed in miles per hour; for example, an engine having 63″ drivers, makes 15 revolutions in 11.2 seconds, according to the table, the rate of speed would be 15 miles per hour.

For the high speeds the time consumed between mile posts is most convenient and is shown as follows:

TABLE OF TRAIN SPEEDS

If a train covers the distance between two mile posts in the number of seconds given in the table below, the speed in miles per hour will be as shown:

Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour
120	30.0	84	42.9	68	52.9
115	31.3	83	43.4	67	53.7
110	32.7	82	43.9	66	54.5
105	34.3	81	44.4	65	55.3
100	36.0	80	45.0	64	56.2
95	37.9	79	45.6	63	57.1
94	38.3	78	46.1	62	58.0
93	38.7	77	46.7	61	59.0
92	39.1	76	47.4	60	60.0
91	39.6	75	48.0	58	62.0
90	40.0	74	48.6	56	64.2
89	40.4	73	49.3	54	66.6
88	40.9	72	50.0	52	69.2
87	41.4	71	50.7	50	72.0
86	41.9	70	51.4	48	75.0
85	42.4	69	52.1	45	80.0

These suggestions apply equally to accelerating a train from its start. The engineman knows from experience that to obtain the maximum starting power, the reverse lever must be placed in full gear and as speed is attained the reverse lever must be hooked up as the speed increases, since allowing the reverse lever to remain in the corner prevents an increase in speed above a certain point, and as an increase in speed can only be obtained by increasing the power of the locomotive it is evident that there is a proper position of the reverse lever in proportion to the speed which produces the maximum power. The practice of allowing the reverse lever to remain in full gear in starting until a considerable speed is attained and then hooking the reverse lever up to a short cut-off at one time should be discouraged if it is desired to attain the maximum speed in the shortest possible time. The proper method is to hook the reverse lever up a notch or two at a time as the speed increases until the shortest cut-off at which the engine performs satisfactorily, has been reached, the throttle opening is to remain as near full open as the operating conditions will permit.

By giving these matters proper thought and acting on the suggestions offered, an improvement in the performance of the locomotive can readily be effected where there is room for such improvement.

CONDENSATION

Since the steam is expanded twice in the compound engine, and passed through a greater number of passages on its way to the cylinders, the chances for condensation are greater than with the simple engine, and for that reason more care must be exercised in ridding cylinders and valve chambers of water.

In freezing weather, if steam pressure cannot be maintained upon the boiler, drain the water out of injectors, air pumps, lubricators, feed and branch pipes, stoker cylinders, coal pushers, also the boiler and tender if there is danger of freezing. If there are no drain cocks to provide for this loosen the joints in such pipe connections as may be necessary to let the water out.

If the inability to maintain steam pressure is due to grates being burned out or broken, repairs can be made by using angle bars or scrap iron to cover the broken grates. Before proceeding it should be known that the ash pan is cleaned sufficiently to admit plenty of air.

SAFETY VALVES—STEAM GAUGE PRESSURE

Steam pressure as indicated on a steam gauge, is the pressure of the steam above atmospheric pressure, which is 14.7 pounds at sea level. To prevent the steam pressure from rising above that specified for the boiler, safety valves are provided. These are usually located on top of the steam dome, although in many cases they are located on an individual or auxiliary dome smaller than the main steam dome. The safety valves are for the purpose of relieving the pressure in the boiler in case it rises above the amount for which the safety valves are adjusted. With modern locomotives two or more safety valves are applied, so that in the

event of one becoming inoperative, or if it does not properly relieve the pressure, the others will operate. The duty of the boiler is to generate steam only for the purpose of performing useful work, any escape of steam which does not perform some such work is a total loss. Therefore do not generate steam faster than it is used, and permit it to be blown away through the safety valves. Ordinarily if the safety valves pop or blow off for one minute, enough steam is blown away to necessitate burning one shovelful of coal or about fifteen pounds. This coal and the labor of handling it is a total loss.

USE OF BLOWER AND MOVING ENGINES

The excessive or unnecessary use of the blower is forbidden. In cleaning fires or working about the firebox, the blower should only be used heavy enough to carry away the dust and gases. The blower should not be used heavily unless the firebox contains a fire similar to that which obtains when the engine is working steam—that is, a good hot fire all over the grate surface.

Never move an engine unless it is known that the engine is in condition to move, that the proper pressures are available for operating the brakes, reverse gear, etc., and that there is no one working under or around the engine who may be injured by such moving.

GRATES AND FRONT END APPLIANCES

Move grates but slightly on any occasion when engine crew is in charge. When the rocking intersecting finger style of grate is shaken too hard, the cinders and dead ashes are thrown up into the fire where they fuse or melt and run to the grates and harden into clinkers or slag, causing hard working or stuck grates. Excessive use of the rake will produce a similar result. Therefore grates should be shaken very lightly, just sufficient to break any crust that may be forming below the fire. Sometimes one is tempted to break up a banked fire by giving the grates a violent shaking. Do not do so, but use the rake lightly instead.

Should anything occur in the front end or smoke box to obstruct the free flow of air or gases from the flues to the smoke stack, the steaming qualities of the engine will be interfered with. Such obstructions may occur on account of the front end netting being stopped up with cinders; the netting is placed in the front end to prevent large cinders from passing through which might set fires to grass weeds, or wooden structures along-side the track. The draft plates may be out of place, which would obstruct the proper flow of air and gases. The steam pipes or nozzle joints may be leaking, which would tend to blow the gases back toward the firebox. In the case of superheater engines, the unit joints may be leaking or the superheater tubes may be split or leaking, which would have the same effect as the steam pipe or nozzle joints leaking.

MAINTAINING WATER IN BOILER

In closing the throttle, if it is found that the water in the boiler lowers so that there is no indication of water in the water glass, the throttle should be again opened to maintain the water in sight in the glass, if possible; and the water supply to the boiler increased until the throttle may be closed without causing the water to lower to a point where the water glass will not register the water level. Otherwise the fire should be deadened in order to avoid overheating the firebox and crown sheets.

POOR STEAMING QUALITIES

When an engine fails for steam the engineer should, at the first opportunity when it is safe for him, watch the performance of the fireman as to whether the engine is apparently being properly fired. See whether the conditions in the firebox are good or bad. If the method of firing is apparently good and the fire is maintained in as good condition as possible and it is necessary to stop on account of low steam, it should be determined if the engine is leaking in the firebox, or if there is any obstructions in the ash pan that would interfere with the proper admission of air to the fire. See that the fire is clean, so that the air can get through. Inspect the outside of the front end to find out whether or not something has gone wrong that would admit an excessive amount of air to the smoke box. It may be that the hand-hole plate is missing, or that for some other reason too much air is being admitted to the smoke box.

Proceed as soon as sufficient steam and water is had to permit. If the conditions are very bad, necessitating excessive delay, and the trouble has not been located, examine the interior of the front end to see that the draft plates or pipes have not become loosened and out of place. This should be particularly looked out for if the engine is located on a branch line where forces to carry out such work are limited. The fire should be kept as clean as possible, cleaning the fire if necessary to accomplish this, and proceed to the best advantage that the conditions will permit.

Do not stop to blow up for steam unless conditions make this necessary, favor the engine at every opportunity, such as drifting on descending grades, or by working the engine lighter. Avoid as far as possible using the injector when engine is not working steam. Make every effort to discover the cause which is effecting the steaming qualities of the engine, making proper report so that repairs might be made.

WORK REPORTS

Do not make blanket reports. In reporting leaks in firebox report definitely the location of all leaks observed on the trip. The conditions when the engine arrives in the roundhouse may not disclose them as readily as when engine was hot and working.

On arrival at terminals inspect the engine thoroughly, make a thorough inspection in the cab of all fittings and appliances, examining the firebox sheets and flues, arch and arch tubes. Inspect thoroughly the connections between the engine and tender. Also give all parts of the engine and tender a thorough inspection, reporting clearly and definitely all necessary work which should be performed. In making reports of any kind endeavor to make them in a clear manner so that there can be no mistake as to their meaning. Report all necessary work on engines under your charge on arrival at terminals.

USE OF SAND TO PREVENT DRIVING WHEELS SLIPPING

It is well known that the use of sand will cause the wheels to grip the rails and thereby reduce the liability of drivers slipping or wheels sliding. When the rails are slippery, such as is the case during rainy or frosty weather, the adhesion between the wheel and rail is very low, therefore even light brake applications may cause the wheels to slide, particularly at low speed and under these conditions enginemen should use care to see that the rail is sanded whenever there is liability of wheels slipping or sliding when starting or stopping trains or engines.

In starting from state of rest, sand should be used until sufficient speed is attained so that slipping will not occur. The slipping of drivers is very destructive to rails because the drivers will cut grooves into the rails which later may cause the rails to break as trains pass over them at high speed. It also wears the driving tires rapidly and causes a waste of coal and water, in addition enormous strains are set up throughout the frames and driving axles and other parts of machinery which may later on lead to failure of these parts.

If the drivers do slip, never apply sand while the wheels are slipping, because to do so may cause the pair of wheels which receive sand first to stop slipping suddenly, the frames, rods, and crank pins are then required to stop the other pairs of wheels at the same instant which causes very damaging stresses. This contributes to broken crank pins, driving axles, frames, side rods, fractured cylinder castings, cylinder heads and other damage to machinery. Always close the throttle to stop slipping before applying sand to rails.

The sand pipes on both sides of an engine should be kept open because if the sand only runs on one rail the wheels on that side will grip the rail while those on the other side may tend to slip, setting up very heavy twisting stresses in the axles and heavy stresses in crank pins, rods and frames.

If sand is applied while an engine is slipping, with the sand operating on only one side, it increases the chances for failure of side rods, crank pins, axles and other parts of machinery.

In stopping, sand should be used at least thirty or forty feet before stop is completed and a greater distance than this if the rail is in bad condition and wheel sliding liable to occur. Engine-

men should make a regular practice of stopping with the engine driving wheels on sand, as stated above, whether the rail conditions are good or bad. Any defects in sanders, piping or other conditions which prevent the proper operation of sanders should be promptly reported.

Special instructions prohibit the use of sand at certain locations, otherwise sand should be used in all stops, and starts, or to prevent slipping, while moving.

In ascending grades or curves, where engines are being worked heavily at low speeds, particularly with engines having long wheel base, there is more tendency for slipping than is the case with engines having a short wheel base. Under these conditions use sand frequently, even though slipping does not occur, particularly during weather when moisture accumulates on the rail, and there is liability of moisture accumulating in the sand pipes. Operating the sanders frequently maintains them in an operative condition.

The best practice is to use sand intermittently for short periods, say a few seconds at a time. The application being only sufficiently frequent to prevent slipping. On approaching road crossings, or other points where the rail conditions may be unusually conducive to slipping, apply sand before slipping occurs, the idea being to protect the engine against slipping in advance as far as it is possible to do so.

On heavy grades and curves it may be necessary to use sand almost continuously, if possible avoid using a heavy layer of sand. Large quantities of sand on the rail add to the resistance of the train. If necessary to avoid slipping use the maximum amount of sand obtainable.

When handling a long heavy train do not let the speed reduce to a point where bad slack action is set up throughout the train on account of slipping, due to sanders not working. Such a condition is brought about by the speed falling to a point where one end of the train stops or nearly stops when slipping occurs. If the slack is jerked out of the train heavily each time after slipping occurs, it is advisable to stop and get the sand pipes open. Continued slipping under these conditions very often causes the train to part.

The tractive power, or cylinder power of the modern engine is very close to the wheel adhesion on the rail, that is, a great margin in weight on the wheels is not allowed over the power of the cylinder to turn the wheels, therefore, if the rail is not dry the adhesion is very much reduced and slipping of the driving wheels occurs very easily, therefore do not attempt to start an engine suddenly under any condition. Do not forget that when an engine is operating on curves, that the wheel adhesion on all driving wheels is not uniform, and that slipping is more apt to occur when working an engine at low speeds and under heavy work; the power in the cylinders will, many times, apparently switch the entire locomotive from side to side. Under such conditions look out for slipping. Slipping the driving wheels is throwing away power that should be used to propel the engine, and tires and rails are badly damaged. Repetition of this necessitates their renewal. When slipping occurs one pair of wheels is liable to stop slipping or attempt to stop considerably in advance of another pair. This

throws very heavy stresses on crank pins, rods, frames and their connections, therefore do not use sand while an engine is slipping, even with the throttle closed; wait until the engine stops slipping, then start the sand. When the sand pipes operate only on one side, make it a point to get the other sand pipe operating, or else avoid the use of sand entirely, if possible. Slipping of engines is the most prolific cause of progressive fractures which finally result in serious break-downs. Violent slipping of the driving wheels may result in the failure of side rods or other parts which may lead to the personal injury of the engineer or fireman.

When rail conditions are so bad that continued slipping of the drivers takes place, even though sand is used, do not attempt to work a heavy throttle with the reverse lever hooked up toward the center. Work the reverse lever near full stroke with only sufficient throttle to keep the train moving, until conditions are such that the speed may be increased and the reverse lever hooked up and the throttle opened wide. The above method should be resorted to only in cases where the rail conditions are very bad, or where continued slipping occurs, such as might be the case in handling heavy trains in starting or on ascending grades, etc. Working a light throttle under these conditions reduces the tendency for the drivers to slip, and if the wheels do start to slip the steam pressure in the cylinders reduces rapidly so that violent slipping does not take place.

LABOR SAVING DEVICES

Mechanical Stoker

The mechanical stoker is designed to relieve the fireman of the labor of firing by hand, the stoker firing the locomotive mechanically, with small coal scattered over all parts of the grate area continually. This continuous delivery of coal in small particles over the entire grate area is under the fireman's control. Since there is no manual labor connected with the operation of such stokers the maximum capacity of even the heaviest locomotives might be obtained without taxing the strength of the fireman.

The operation of the mechanical stoker and the travel of the coal is illustrated by numbers in Fig. 34, and is as follows:

The shovel sheet is provided with an opening 18 inches wide, extending from the coal gates to the slope sheet of the tank. The opening is covered by slides each measuring about 20 inches in length. After passing through this opening to the trough (1) beneath, the coal is conveyed by the helicoid Conveyor Screw (2) through the crushing zone (4)—where the coal forced against the crusher plate by the screw is broken to a suitable size—to the Transfer Hopper (9), where it is divided, equally or unequally, according to the position of the dividing rib (18), between the two Elevators (10) and (19). In these Elevator Casings are Elevator Screws (11), which elevate the coal and drop it into tubes fitted into Elbows (16) and (17), which tubes extend through holes in the back-head on each side of the fire door. Constant steam jets in the elbows blow the coal through the tubes above mentioned, which are fitted with Distributors (11) and (12), located on the inside of the firebox. These distributors deflect and spread the coal over the entire surface of the fire.

The elevating screws are driven by gears which mesh with a rack reciprocated by the Driving Engine (5), and the conveyor screw is driven by a Driving Shaft (26), also meshed into this rack, secured along the side of the trough and geared at (32).

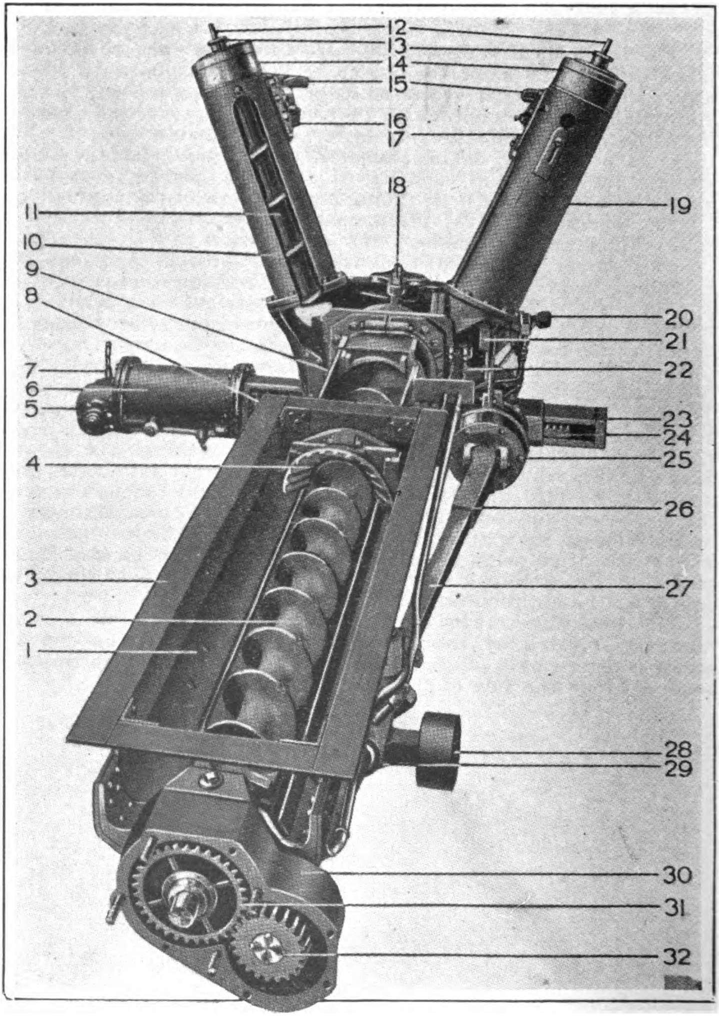

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Fig. 34.

DRIVING ENGINE

Fig. 35 shows the driving engine which consists of a cylinder of eleven-inch bore and a stroke of seventeen and three-quarter inches, with piston and reverse head. It is operated by steam taken from the locomotive turret reduced in pressure by throttling through a one-half inch globe valve.

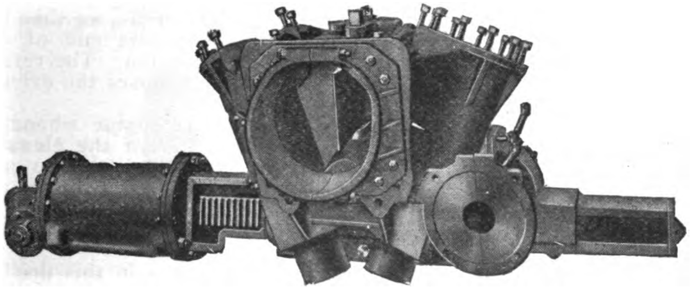


FIG. 35.

The pressure of the steam used by this engine varies from eight to eighty pounds, according to the work required by the quality and size of the coal, and its pressure is indicated by a special driving engine steam gauge located on the boiler head, connected in this line between globe valve and cylinder. In normal operation, the piston has a power stroke in one direction only. This is when the piston is traveling in toward the center line of the locomotive and the entire stoker mechanism is in normal operation, since on the return stroke of the piston the conveying mechanism is stationary; but when any one or all of the three screws—two elevator and one conveyor—are reversed by means of their individual reverse mechanisms, the return stroke of the piston becomes temporarily a power stroke. By this it can be seen that only a very small percentage of the full boiler pressure is required for the return stroke except when the reversing of any of the screws is necessary.

The operation of this cylinder is controlled by a reverse head, to which is connected by proper ports and passages, almost identical with the reverse head used on the Westinghouse eleven inch air pump, although not interchangeable. The piston rod screws into the rack or stoker main driver, hereinafter described. The reverse head is bolted to the outer end of the driving engine cylinder, and the admission ports to the cylinder are so arranged that if the piston makes a sudden movement, such as might be the case if a clog occurred in the conveyor or elevators, and then broke loose,

a small percentage of the steam is trapped in either end of the cylinder which forms a cushion to prevent breaking the piston or knocking off the reversing head.

The reverse head is operated by means of a small reverse rod which operates in the hollow piston rod, in a manner identical with the reversing rod used on Westinghouse air pumps.

In case the stoker becomes clogged on any foreign material, or it is desired to reverse it for any reason, the operating rod located on the back head of the locomotive boiler, if the piston is making a power stroke, is moved to its lower position, and if the piston is making a return stroke, to its upper position. This moves a small valve in the auxiliary head bolted to the reverse head, so that the reverse head valve throws steam into the opposite end of the cylinder and causes the piston to change its direction. The return of the operating rod handle to a central position causes the driving engine to resume its normal operation.

It is always necessary to reverse the driving engine whenever a clog occurs and it is desired to reverse either of the elevator screws or the conveyor screw. The reason for this is that in case of a clog the pawls in the elevator or conveyor screw reverses are held so tightly against the ratchet wheels that it is impossible to lift them from the teeth unless the pressure is relieved by reversing the driving engine.

Unlike the ordinary high speed engine, there is in this driving engine an enormous reserve power, which is absolutely necessary for the work to be performed, i. e., the crushing of coal with its varying physical properties. With the low steam pressure needed by this engine for normal operation, and the great differences between it and main steam line pressure, it can be seen that when the task to be performed increases it is merely a question of the steam pressure building up in the cylinder to the point required for that task.

DISTRIBUTION OR SPREADING SYSTEM

The starting of the coal towards the two firing zones or areas in the firebox is done by the elevators, as explained, but the actual spreading of the coal over the two overlapping zones, or areas, is accomplished through the means of the two firing points at the two stoker openings through the back-head of the locomotive boiler. The fire door is left undisturbed so that it can be used for hand firing at roundhouse and on sidings, or when drifting.

Two elbows, Fig. 36, in the back bottom portion of which firing nozzles are secured by means of set screws, are bolted to the elevator casings. Distributors and tubes combined are attached to these elbows, the tube extending through the openings in the back-head and the distributor being on the inside of the firebox.

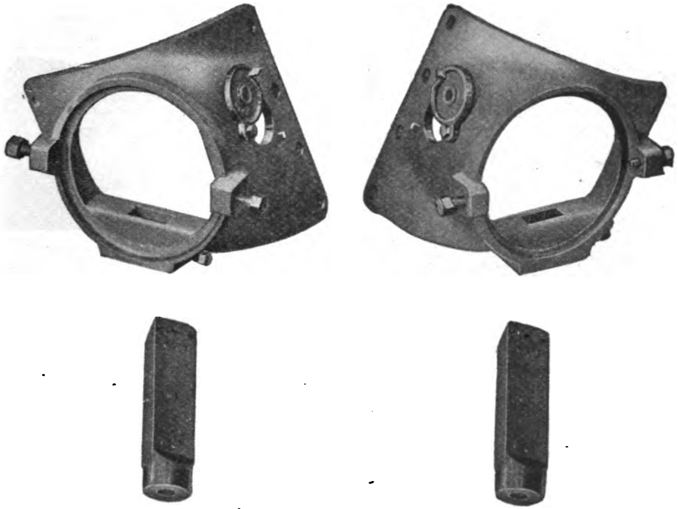


FIG. 36.

The distributor tubes serve as a firing plate and the coal is blown through the tubes on the under side of the distributors by the jets of steam admitted to the firing nozzles, an intermittent action being secured through the constant steam jet and the stopping of coal elevation during the return stroke of the driving engine piston and rack.

The elbows are provided with peep holes with swinging covers through which the coal supply can be observed, and the condition of the fire can be seen through peep holes in the tops of the elevator casings.

The deflecting ribs on the distributors are so arranged as to distribute the coal in such a manner that all parts of the grate area will be served to the best advantage, the two firing zones, or areas, overlapping along the center where the combustion area is greatest.

The distributor tubes are made of cast steel and are of the design shown in Fig. 37. They are secured to the elbows by means of bolts and it is but a moment's work to replace them when necessary.

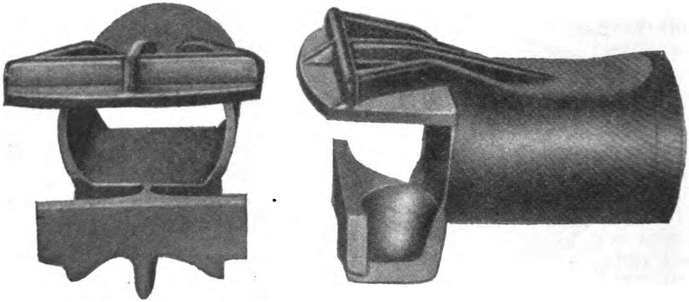


Fig. 37.

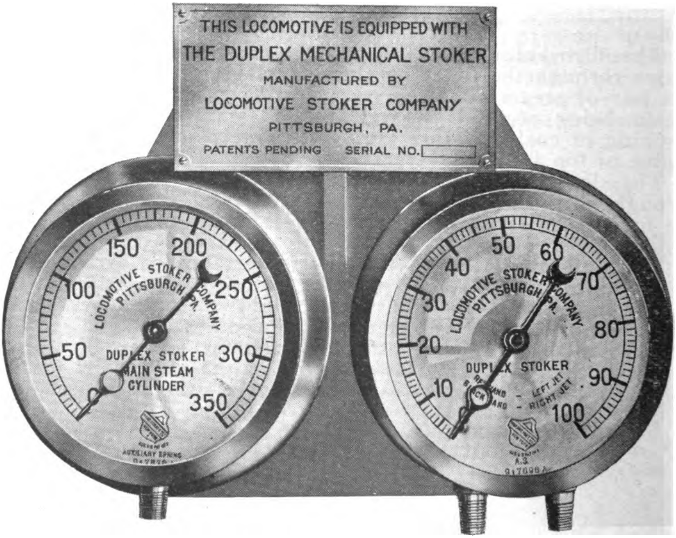

THIS LOCOMOTIVE IS EQUIPPED WITH
THE DUPLEX MECHANICAL STOKER
MANUFACTURED BY
LOCOMOTIVE STOKER COMPANY
PITTSBURGH, PA.
PATENTS PENDING SERIAL NO.
LOCOMOTIVE STOKER COMPANY
PITTSBURGH, PA.
50 100 150 200 250 300 350
MAIN STEAM
CYLINDER
LOCOMOTIVE STOKER COMPANY
PITTSBURGH, PA.
10 20 30 40 50 60 70 80 90 100
STOKER

Fig. 38.

GAUGES

Fig. 38 shows the two steam gauges which are set in a bracket, secured to the back-head of the locomotive boiler in a position where they can be easily read by the fireman.

The driving engine gauge on the left indicates the pressure of steam used by the driving engine. The one on the right has two indicators, the red indicator showing the steam pressure on the jet in the left elbow, and the black indicator, the pressure on the jet in the right elbow.

OILING

All stokers should be oiled before leaving terminal, and on long divisions oil holes should be filled between terminals. The points of oiling are as follows:

The driving engine is oiled by tapping into the driving engine steam inlet line an individual small lubricator. The valve to which should be turned on before starting stoker.

Before the locomotive is put in service either new or after an overhauling in the shop, the rack in the rack housing should receive an initial mixture of one quart of black engine oil. There is a one-inch elbow tapped into the separator cover on the left back side of the rack housing provided for this purpose.

Left and right elevator drivers and reverses are lubricated by lifting the pawl shifters on top of the elevators. When first putting stoker into service about one quart of oil should be poured into each reverse in this manner.

Small holes are located in elevator drive and reverse casings each of which leads to a cored passage in casing provided to lubricate bearing on which elevator drive and reverse rotates.

The left elevator driving shaft bearing in bottom of transfer hopper is lubricated by a special tap on the left side of transfer hopper under locomotive deck.

The right elevator driving shaft bearing and the conveyor drive and reverse receive their lubrication through an oil box, usually stuffed with curled hair, with four outlets. This box, which should be filled every day, can be reached through an opening in the locomotive deck a little to the right of the right elevator. This oil box should be cleaned out occasionally particularly when considerable dust and dirt has accumulated.

The conveyor driving shaft bearings in the slide support and gear casing are oiled by cups secured to the trough under the apron between locomotive and tender. These should be filled at least once a day.

The grease boxes in the gear casing and gear casing cover on the rear of the conveyor should be filled at least once a month with soft grease and once in three months the gear casing cover should be removed and the gears packed in grease.

Universal joints, slip joint and conveyor slide support rollers should be oiled once a day with engine oil.

Use valve oil in the lubricator for the driving engine. Use engine oil for other parts, except the conveyor gear casing. See

that the lubricator is feeding when the stoker driving engine is running. When the stoker engine is shut off, such as in standing or drifting, shut the lubricator off.

TO START AND OPERATE STOKER

Referring to Fig. 39. First open main valve No. 1 at the fountain, then open valve No. 2, next open valve No. 3, which allows the steam to flow to the distributor jet line. Valves Nos. 4 and 5 should then be opened sufficiently to register about 15 pounds upon the jet steam gauge. Always see that steam is blowing through the jets before starting the stoker engine.

To start the stoker engine place the operating lever No. 10 in its central or running position. Place conveyor reversing lever No. 12 in forward position. See that valve No. 8 to the exhaust line is open. Valve No. 9 should be kept closed except when it is desired to moisten the coal with exhaust steam. See that the lubricator to the stoker engine is feeding properly. Valve No. 6 should be opened slightly and allowed to remain in that position until the stoker engine has made several strokes slowly, if the stoker engine has been standing some time, in order to work the condensation out of the stoker engine cylinder. Valve No. 7 should be kept closed except when necessary to obtain more power to crush a particular hard lump of coal. When this valve is open steam pressure increases very rapidly in the stoker engine cylinder. As soon as the heavy duty crushing is performed valve No. 7 should be closed, and the stoker operated with steam through valve No. 6.

Open the first slide plate No. 29, in the floor of the coal pit of the tender, by pulling it ahead with a hook. This allows coal to feed into the stoker conveyor. The slide plate should not be opened full length, but just far enough to feed coal at the proper rate to the conveyor. When lump coal is used the slide plate must, of course, be opened wider than with slack coal.

The stoker should be run slowly at first, feeding just sufficient coal to supply the fire for the work being done by the locomotive. On extra light runs the stoker will have to be shut off frequently for short intervals. Do not feed too much coal, carry a light fire. In firing with the stoker the fire should be lighter than is the case in hand firing.

To reverse the conveyor screw in the tank lower handle No. 10 to bottom position. Move screw conveyor reverse lever No. 12 to rear or reverse position. Raise handle No. 10 to center position. This reverses the screw in the tank.

To stop conveyor screw in tank place conveyor reverse lever No. 12 in center position. If reverse lever No. 12 does not move freely lower handle No. 10 to bottom position and then to center before attempting to move the reverse lever.

CAUTION

Return stoker piston to dead position against cylinder head by lowering handle No. 10 and shut off steam to stoker engine by closing valves in steam line before trying to remove obstructions in stoker or doing any work on stoker.

Keep hands out of stoker elevators and conveyors unless steam is shut off to stoker engine and handle No. 10 moved to its lowest position.

Do not put a bar, rod or lever in stoker unless the above precaution is observed.

Do not step in the stoker conveyor.

To reverse the right or left elevator screw raise the pawl shifter No. 26 on top of vertical shaft to upper position. Stop the conveyor screw before reversing the elevator screws or the stoker will be jammed with coal.

To stop the right or left elevator screw raise elevator pawl shifter No. 26 on top of elevator to middle position. Stop the conveyor before stopping the elevators or the stoker will be jammed with coal.

TO LOCATE CLOGS

In case the stoker stalls due to iron, slate or other foreign matter getting into the stoker machinery, first shut off steam pressure to the stoker engine cylinder by closing valves Nos. 6 and 7, move operating lever No. 10 to its lowest position, place the tender conveyor reverse lever No. 12 in center position, then place the right elevator pawl shifter No. 26 in its neutral or middle position. Now raise the operating valve lever No. 10 to its central position and open the steam valve No. 6 sufficiently to run the left elevator to determine whether the obstruction is in the left elevator. If the left elevator operates properly cut in the right elevator by lowering pawl shifter No. 26, without increasing the steam pressure. If the stoker stops, evidently the obstruction is in the right elevator. If the stoker continues to operate properly the obstruction is in the tank conveyor.

TO REMOVE CLOGS

DO NOT FORGET TO SHUT OFF THE STEAM TO THE STOKER ENGINE CYLINDER, BY CLOSING VALVES NOS. 6 AND 7, BEFORE ATTEMPTING TO REMOVE OBSTRUCTIONS OR WORK UPON THE STOKER.

The clogs in the upright elevators usually occur at the bottom of the elevator casing doors, catching between the flight of the conveyor and the bottom of the door.

To remove these clogs, raise the door in the engine deck and the obstruction can usually be seen and removed. However, if it is in the elevator, reverse the elevator screw forcing the obstruction back down into the transfer hopper. In case the obstruction is not located at this point it may be a small mine spike or other piece of metal which has gotten above this point. In that case

remove the nut at the top of the elevator casing door, remove the door and the obstruction may be located and removed.

A clog in the tank conveyor will usually be found in the crusher zone. To remove a clog at this point reverse the tank conveyor screw in the manner described, forcing the obstruction out of the crusher when it can be removed from the trough.

Do not run the conveyor screw backward more than three revolutions.

COAL DISTRIBUTION IN FIREBOX

The distribution of coal is regulated by two separate attachments as follows:

Steam jets in elevator elbows.

Dividing rib in transfer hopper.

The steam jets fitted into the elevator elbows blow the coal over the grate area and are regulated according to the quality of coal. For coarse coal it requires about 18 pounds of steam, and for slack about 9 pounds of steam, on these jets to get an even distribution. The coarser the coal the more steam, and the finer the slack the less steam will be required. If, after running for some distance, it is found that too much coal is going to the flues, the steam pressure on the elbow jets should be reduced, and if not enough is going to the flues, it should be increased.

The dividing rib in starting out should be in the center of the transfer hopper. If it is found that too much coal is feeding to the right side of the firebox, the dividing rib should be turned to the right, and if too much is feeding to the left, the dividing rib should be turned to the left.

The amount of coal distributed over the firebox is regulated by the speed of the driving engine and the plates over the trough in the tender. To vary the amount of coal, the steam pressure should be increased or decreased by regulating the controller valve 6, Fig. 39. When it is seen that not enough coal is feeding into the trough another slide over the trough should be pulled back.

Before leaving terminal, see that fire is clean and in good condition. Build up a good level fire with shovel. After starting stoker as hereinbefore explained, open one or more slides in tank and be sure coal is getting to conveyor screw.

Do not feed iron, rock, slate or waste through the conveyor.

When train is standing on siding for a short period, shut stoker off by throwing operating rod on back-head of locomotive boiler out of running position. When train is to stand for a longer time, the driving engine should be cut out entirely by closing main steam line inlet and main lubricator connection and **in winter time drain cocks should be opened.**

If sufficient coal cannot be supplied front grates see if the distributors are warped out of shape and point too low. If such is the case, report should be made at terminal so that proper adjustment may be made. See that the steam jets are blowing freely, and are not plugged with pipe scale. It may be necessary to increase the pressure on these jets.

Before leaving a stoker engine at fire track, fireman should close the slides in tank and let driving engine run long enough to remove **all coal** from conveyor, close driving engine throttle valve and steam jet main line valve tight, open drain cock on bottom of engine cylinder to eliminate any possibility of stoker engine freezing in extremely cold weather, and shut off the stoker lubricator.

METHOD OF OPERATION

In firing with the stoker the practice is to build up a light even fire by hand and get up full steam pressure before leaving a terminal, and not bring the stoker into use until the locomotive is working steam. The fireman then opens distributor jets and starts driving engine, then opens first coal slide plate over conveyor trough, which starts the delivery of the coal to the firebox.

The screw conveyor is designed to furnish the amount of coal required under average conditions with stoker engine running at or below medium speed.

As this stoker is of positive feed throughout, the physical condition of the coal is not changed except when too large, and it will take wet coal just as easily as dry. This moisture is desirable, especially when the percentage of slack is large, and an arrangement has been made for dampening the coal when necessary by a connection between the steam exhaust of the driving engine and the transfer hopper.

When the first of the slide plates is pulled forward, the coal, falling into the conveyor beneath, is carried by the heavy cast steel conveyor screw through the crushing zone at the forward end of the trough. Through this zone the slack and coal of a size suitable for efficient firing passes in a loose and free state without being crushed, while the large coal is broken and reduced to the best size for efficient firing. After passing through this zone the coal is delivered to the transfer hopper beneath the cab deck, where it is divided, equally or unequally, according to the position of the dividing rib, between the right and left elevators, and dropped into distributor elbows. Into these elbows are fitted distributor tubes which extend through the openings in the back-head on each side of the fire door, the distributor portion of each tube being located on the inside of the firebox over the grate area.

The distribution of coal over the grate area is accomplished by means of a low pressure constant steam jet located in the back and bottom portion of each distributor elbow. The pressure of the steam supplying the right and left jets is reduced from boiler pressure by throttling it through half inch globe valves, and this reduced pressure is indicated by a steam gauge connected to each jet line between globe valve in that line and elbow jet nozzle. The pressure of steam at these jets under working conditions varies from ten to twenty-five pounds. Interposed between the jet valves and the main steam line is a three-quarter inch globe valve, by which the steam may be cut off from the jet main line without disturbing the setting of the jet valves.

The distribution of coal over the grate area is regulated by varying the pressure of the elbow jets, as indicated by its idividual pointer on steam gauge fastened to the back-head in full view of the fireman. The distributors have deflecting ribs especially designed for their function of spreading the coal, and this variation of jet pressure affects sufficient flexibility in firing different areas of the grate. The distribution overlaps the two areas or zones fired from the two elbows, which overlapping insures ample coal being supplied to center of firebox in heavier combustion area. By increasing the jet pressure on the right or left side more coal will be carried to the flues on that side, or by decreasing the jet pressure less coal will be carried to the flues and more to the middle and back portion of the grate area on the particular side.

The deflecting ribs on the distributors, as shown in Fig. 37, place some of the slack coal in right and left corners of firebox, thus preventing loss through stack. The fireman can direct more or less coal to each side of the firebox by changing position of the dividing rib, as shown in back view of transfer hopper, Fig. 35, by moving lever to either side.

By means of the elevator reverses and conveyor reverse, which as hereinafter described are an arrangement of ratchets and pawls, the two elevator screws and conveyor screw turn in one direction only, and coal is therefore conveyed and elevated only on the forward stroke of the engine. In this manner constant steam and intermittent supply of coal is secured.

The sliding plates at the bottom of the tank are located so that there will be a supply of coal at all times on top of the screw.

As coal is used from tender so that it no longer flows freely through first slide opening, the fireman opens next slide and so on until supply is again taken at coal chute, when slides are all pushed back and first slide opening used as in starting out.

With the distribution as described, a level white fire can be carried and perfect combustion secured. This level thin fire usually results in the firebox temperature being four or five hundred degrees higher than with hand firing. Maintain a white level fire, and if the engine has been steaming well for some distance and steam begins to reduce, do not materially increase the amount of coal being fed to the firebox, unless there has been a change in the working of the engine or an increase in the amount of water being supplied to the boiler. Observe if the fire needs attention. Forcing the stoker under such conditions causes clinkers to form which shuts off the supply of air through the grates, causes the fire to bank and become heavy and contributes to heavy losses of fuel.

Before taking coal close the tank opening with the slide cover plates. This should be done before any coal is put in the tender.

When it is desired to separate the engine and tender, the conveyor unit of the stoker should be left with the tender. This can be done by loosening the bolts on the left ball joint clamp and sliding the clamp to the left enough to free the conveyor ball joint and disconnecting pin connecting the block and universal joint jaw on the conveyor drive and reverse cover.

Don't leave the tank openings uncovered when coaling the tender.

Don't let coal stand in the conveyor trough between trips.

Don't allow coal to accumulate in the tank cut-out and become packed around the outside of the conveyor trough. This will break the trough when the locomotive is rounding a curve.

Never place a hand or foot in the trough while stoker is in motion.

Don't run the stoker without distributors. The distributors are designed to spread and save coal. Leaving them off means unnecessary waste of coal.

POWER REVERSE GEAR

In order to reduce the labors of the engineman, many engines are equipped with the power reverse gear, shown in Fig. 40. Consisting of a cylinder, the piston of which is attached to the reach rod connecting with the reverse shaft arm, a reverse lever in the cab connects to a system of levers which control the movement of the piston in proportion as the reverse lever is moved forward or back.

Pressure for operating the reversing piston may be taken from the main air reservoir, or steam pressure from the boiler may be used. When the reverse lever in the cab is moved into forward gear, a floating lever moves a slide valve located in a valve chamber on top of the cylinder, admitting air to the proper end of the cylinder to move the piston in the proper direction to cause the valve gear to move to forward position. At the same time any pressure on the opposite side of the cylinder piston is exhausted to the atmosphere. As the piston moves the valve gear as described above, a connecting link which is attached to the piston rod crosshead, operates a combination lever which automatically carries the slide valve to its central position, at which time the supply of pressure to the cylinder is cut off and the exhaust to the opposite end of the cylinder is also closed, thus stopping the piston if it has moved an amount corresponding to the movement of the reverse lever in the cab.

When the reverse lever in the cab is moved to the backward motion, the gear operates as described to set the valve gear for a backward movement of the engine. When the reverse lever in the cab is placed in its central position the piston in the reverse gear cylinder moves to the center of the cylinder, at which time the slide valve cuts off the pressure, causing it to remain in that position.

It can be seen that a movement of the reverse lever either slightly forward or backward of its central position, causes a slight movement of the piston in the reverse gear cylinder, thus providing for moving the valve gear to a position corresponding to that of the reverse lever in the cab from full forward to full backward positions.

Before attempting to operate the reverse gear it should be known that ample air pressure is in the main reservoir and that the main reservoir valve, admitting air to the reverse gear valve chamber, is open.

The cylinder is oiled through a small lubricator or oil cup, located on the top of the reverse gear valve chamber, and all moving parts should be lubricated from the oil holes provided for that purpose.

If no air pressure is available, provision is made for admitting live steam from the boiler to the valve chamber by opening a valve located in the cab. Steam should only be used in cases of emergency. Always report having turned steam on reverse gear so that the cylinder packing may be given attention and new seal applied to steam valve in cab, on account of necessity for breaking the seal when steam is applied to the reverse gear.

Leakage from the cylinder around the piston rod causes a loss of pressure which is a continual drain on the main reservoir when the engine is working steam, and also tends to cause the gear to creep forward after the slide valve has cut off the supply of air to the cylinder.

Leakage by the cylinder piston packing rings causes the air to leak from one end of the cylinder to the other, which, when the engine is working, causes a continual drain on the main reservoir and also causes the gear to creep after the slide valve has cut off the supply to the cylinder.

Lost motion in the pins connecting the combination lever and also lost motion in the valve stem, either where connected to the slide valve or at the combination lever, requires additional movement of the combination lever to cause the slide valve to close the ports after the reverse lever is placed in any position. Such lost motion causes the gear to creep without a loss of air pressure, unless there is excessive lost motion in which case the gear may creep far enough so that when the slide valve opens a return movement to its original position may cause the slide valve to open the exhaust port.

Located in the steam pipe leading from the fountain to the reverse gear is a fountain valve for the purpose of shutting off steam from the boiler to the reverse gear. There is also in this steam pipe a three-way cock which closes communication between the boiler and the reverse gear and opens a drain pipe to prevent steam or water passing to the reverse gear valve chamber in case the fountain valve leaks, or does not close tightly on its seat. Therefore, when it is desired to use steam in the reverse gear, the three-way cock should be opened and then the valve in the steam pipe at the fountain should be opened. Opening the three-way cock does not admit steam to the reverse gear valve chamber unless the valve at the fountain is also open. Whenever it is necessary to use steam to operate the reverse gear the fact should be reported on arrival at terminal so that cylinder packing may be examined and cylinder thoroughly cleaned out and lubricated.

pose of connecting the cylinders to the grate shaker levers. Steam pipe connections lead from the operating valve in the cab to each end of each cylinder, for the purpose of supplying steam for moving the pistons in such cylinders. A small lubricator is mounted on the operating valve body, or in the steam supply pipe leading

CAB STEAM HEAT SYSTEM

In order to provide for the comfort of the engineer and fireman during cold weather, locomotive cabs are equipped with an independent system of steam heating pipes or coils. The steam heat pipes or coils are located on the running board under the engineer's and fireman's seat boxes. Connected into the blower steam pipe is a branch pipe leading to a small reducing valve which controls the pressure admitted to the heating coils. A globe valve is located in this branch pipe between the blower pipe connection and the reducing valve to enable the steam to be closed off from the steam heat system.

Leading from the reducing valve is a steam pipe connected to the steam heat pipes or coils on each side of the cab. These two connecting pipes are equipped with globe valves in order that steam may be used in the coils at one or both sides of the cab, as desired, or that the steam may be closed off from the coils on both sides. After the steam passes through the heating coils it is admitted into a steam trap or condensor, in order that the steam will be condensed into water, to prevent as far as possible any steam being passed to the atmosphere which might tend to cause steam clouds around the cab.

A small steam gauge, located in the cab, indicates the pressure carried in the steam heat coils. This pressure should not exceed twenty-five to thirty pounds. To increase the pressure loosen the jam nut and screw down on the adjusting stem located at the top of the reducing valve. To reduce the pressure screw upward on the stem. After the proper adjustments have been made the jam nut should be tightened.

If a heavy flow of steam is had at the steam trap under the cab, the steam trap is not working properly and should be reported for repairs. There should be a very little or no steam showing at the trap when it is operating properly.

For instructions on steam heat for trains see "Instructions for the Operation of Passenger Car Heating and Water Distribution," issued by this Company.

POWER GRATE SHAKER

The power grate shaker, which is provided to reduce the labor of the fireman, consists of an operating valve and cylinders. The operating valve is located on the boiler head at the left side of the cab. A steam pipe connection supplies steam from the boiler to the operating valve. A globe valve is applied in this steam pipe to close off the steam supply from the boiler. The cylinders for shaking the grates are located under the cab deck; the pistons are connected to suitable levers extending inside the cab for the purpose of connecting the cylinders to the grate shaker levers. Steam pipe connections lead from the operating valve in the cab to each end of each cylinder, for the purpose of supplying steam for moving the pistons in such cylinders. A small lubricator is mounted on the operating valve body, or in the steam supply pipe leading

from the boiler to the operating valve, for the purpose of lubricating the operating valve and cylinders. The lubricator should be filled each trip and opened when steam is supplied to the operating valve.

To operate the grate shaker see that the shaker bar is removed from the shaker post which operates the section of grates to be moved, throw back the lock holding such shaker posts, throw in the lock on the center post to connect the shaker post at either side to the center post, turn on steam in the supply pipe to the operating valve and open the lubricator; then move the handle on the right side of the operating valve, if the grates on the right side of the firebox, or on the left side of the operating valve, if the grates on the left side of the firebox are to be shaken. Moving the handle forward causes the shaker post to also be moved forward, the same as when using the shaker bar. Moving the handle backward causes a backward movement of the shaker post. Moving the operting valve to its central position shuts off steam to both ends of the shaker cylinders.

Do not move the handles on the operating valve back and forth too quickly. Move the handle to either the forward or backward position and watch the shaker post, to note whether the cylinder has moved the shaker post to a position corresponding to that of the handle on the operating valve, which it should do. If no movement is observed, the handle should be reversed to the opposite position, allowing the shaker cylinder to move the grate shaker post in the opposite direction. Move the handle of the operating valve back and forth only as fast as the cylinder is able to move the shaker posts. If the handle is reversed too quickly no movement will be had from the cylinders.

There are two cylinders, one for the section of grates on the left and one for the section of grates on the right. The operating valve has two handles, the handle on the right operates the cylinder and grates on the right side of the firebox, and the handle on the left operates the cylinder and grates on the left side of the firebox.

After using the power grate shaker, see that locks for holding the shaker posts in central position are in place and the shaker posts are locked. The locks for holding the shaker posts in position are composed of two parts. If it is desired to move the grates slightly throw out the center part of the lock, this will provide for a slight back and forth movement of the shaker post. When full movement of the grates is desired, throw out both parts of the lock, thus providing for full travel of the shaker posts.

Never attempt to operate the power grate shaker and the shaker bar at the same time. To do so may cause injury to the person attempting to handle the shaker bar.

After using the power grate shaker, shut off the valve in the steam supply pipe to the operating valve and the lubricator. Do not have steam supply valve to operating valve open when shaking grates by hand with the shaker bar.

DESCRIPTION AND INSTRUCTIONS FOR OPERATING THE STEAM COAL PUSHER

The steam coal pusher, designed to eliminate the necessity for the fireman shoveling the coal forward in the tender is shown in Fig. 41, located in the coal pit of an ordinary tender. It will be noted that a steam cylinder is fastened at the top of the slope sheet of the coal pit. Attached to the piston of this cylinder are two crossheads which act to push the coal forward. These crossheads rest at the bottom of the coal pit and when steam is used, the cylinder forces the crossheads forward toward the coal gates, thus pushing the coal forward at the bottom of the pit. This tends to mix the fine coal with the lumps and prevents an accumulation of very fine coal at the bottom of the coal pit.

In operating the steam coal pusher, the following instructions should be observed.

Before starting on trip the coal pusher lubricator, located in the steam supply pipe in the cab, should be filled with valve oil. Do not use engine oil in this lubricator.

A few minutes before using the coal pusher, the coal pusher throttle valve should be "cracked" or opened very slightly, and the lubricator feed adjusted to deliver oil gradually to the coal pusher cylinder.

To operate the coal pusher, open the throttle valve in the coal pusher steam pipe wide open, then open the operating valve on the tank head, at the left of the coal gate, sufficiently to cause the pusher to move. Opening this valve should cause the pusher to move upward, and closing it should cause the pusher to move downward.

When not in use the coal pusher should always be kept at the lower end of its travel. This permits the cylinders to drain properly and enables the pusher to loosen up the coal on the upward stroke before beginning the downward pushing stroke, which requires more power. The coal pusher should always be placed at the lower end of its travel before taking coal.

When coal pusher is not in use the throttle valve in the coal pusher steam pipe in the cab should be kept closed. The lubricator should be shut off and the operating valve on the tank head at the left of the coal gate should be left open.

In freezing weather, the by-pass valve, located in the coal pusher steam pipe in the cab, should be open sufficiently to keep the cylinder and pipes from freezing up. This by-pass valve is a small pipe connection which leads around the throttle valve, located in the coal pusher steam pipe. The purpose of the by-pass valve being to pass a small amount of steam to the coal pusher pipes and cylinders to maintain circulation without building up sufficient pressure to cause the coal pusher to operate.

Do not attempt to operate the coal pusher before the coal gate is free of coal. To do so will either damage the coal gate or pack the coal so as to interfere with subsequent operation of the coal pusher.

If coal pusher fails to work on account of packed coal, remove coal from both front corners of the tender before attempting to operate the pusher.

Coal pushers are to be tested at terminal after each trip. Enginemen should test the coal pusher by operating it before leaving engines on arrival at terminals. If the coal pusher fails to work properly, make necessary report so that repairs can be made before tender is filled with coal.

PNEUMATIC COAL PUSHERS

The pneumatic coal pusher performs the labor formerly devolving on the fireman, and is operated by compressed air. A valve located on the tank head admits air from the main reservoir to two cylinders located on the top of the tender at the back end. The pistons of these cylinders are connected to a large apron which acts as a false bottom for the coal pit. When pressure is admitted to the cylinders the back end of the apron is raised, the front end being hinged to the floor of the coal pit. As the back end of the apron is raised it, of course, assumes a vertical position, which causes the coal to gravitate to the front end of the coal pit.

Opening the valve produces the operation described above, and closing the valve cuts off the supply of air to the cylinders and exhausts air from the cylinders to the atmosphere, allowing the apron to return to its normal position by gravity. Bars are provided which are fastened to the air cylinders, so that when the apron is raised the bars may be dropped down behind the apron to hold it in its upper-most position.

When desiring to operate the coal pusher first consider whether or not there are any interferences, such as bridges, tunnels, etc., that might not clear the coal pusher if it is moved to its upper-most position. In operating the coal pusher the air valve should be opened slowly, noting whether or not the apron starts to raise uniformly on both sides of the tender. At the same time note the air gauge to see if the main reservoir pressure is being reduced while the operating valve is open. If there is much leakage in the pipe connections leading to the cylinders, or in the cylinder packing, pressure may be admitted from the main reservoirs faster than the pump can supply it, in which case the valve on the tank head should not be left open a sufficient length of time to reduce the main reservoir pressure far enough to prevent maintaining proper brake pipe pressure. If the main reservoir pressure is reduced equal to or below the brake pipe pressure, the brakes upon the train may apply, or if this condition is allowed to continue the train may be stopped.

If one side of the apron raises in advance of the other side, the tendency will be to twist the apron badly and loosen it at the supporting hinges; therefore, unless the two sides raises nearly uniform, the pressure should be released by closing the operating valve and the obstruction loosened. Sufficient coal should not be allowed to collect underneath the coal pusher apron near the bottom edge, so that when the apron drops, the coal will act as a fulcrum which may allow the weight of the coal at the top of

the apron to break the hinges or supports loose at the bottom of the apron.

Do not open the operating valve and allow it to remain open, thus holding the apron in its upper-most position continuously. After it is raised and the coal allowed to drop forward as much as possible, close the operating valve and allow the apron to return to its normal position.

If any leakage is observed in the pipe connections or cylinders, or the coal pusher is defective in any manner, see that proper report is made on arrival at terminal.

PNEUMATIC SANDERS

The pneumatic sander replaces the older type hand sander, thus reducing the labor of the engineer. It is designed to provide for placing a continuous stream of sand upon the rail, to prevent engines slipping, a system of pneumatic sanders is installed to each side of the locomotive. A large sand box or sand dome is applied on top of the boiler for carrying the sand supply. The location of this dome is such that the heat from the boiler tends to keep the sand dry after the sand box or dome is filled.

Suitable pipe connections at each side of the sand box lead to the rail in front of the leading wheels, and behind the rear wheels. In some cases the sand pipes are located in front of the second pair of driving wheels and behind the next to the rear pair.

Installed in the sand delivery pipes leading to the rails, is what is called a "sand trap." These sand traps are equipped with small nozzles, and pipe connections lead from the main reservoir, through the cab, and connect to the sand traps in such a manner that as air pressure is passed from the main reservoir to the sand traps the air passes through the small nozzle, blowing a jet of air into the sand delivery pipes. The sand from the sand box flows to the sand traps by gravity and is then blown into the delivery pipes by the air passing through these nozzles. As long as air is admitted to the nozzles and sand flows from the sand box, a continuous stream of sand will be spread upon the rails.

Inside the cab, within convenient reach of the engineer, are located the engineer's sand operating valves. One of such valves being applied to the air pipe leading to the sand trap for blowing sand through the delivery pipe leading in front of the driving wheel and another valve located in the pipe leading to the sand trap and blowing air through the delivery pipe leading behind the driving wheels. The delivery pipes leading in front of the driving wheels are called the "go-ahead" sand pipes, and those leading behind the driving wheels are called the "back-up" sand pipes.

Various types of engineer's valves are used for the purpose of admitting air from the main reservoir to the sand traps. Some of these valves are so arranged that when they are open air is allowed to blow through a small hole in the valve body, which makes sufficient noise to attract the engineer's attention when the valve is in open position. Such openings are called "warning ports," and are provided for the purpose of attracting the engineer's attention, so that he will not leave the operating valve open unintentionally.

In some cases the sand operating valves are of such construction that moving the handle forward operates the sanders leading to the front sand pipes and moving the handle backward operates the sanders leading to the back-up sand pipes.

Some of these valves are designed along the lines of the ordinary plug cock, while others are of the rotary valve type. Leaving the valve open unnecessarily causes a waste of air and also a waste of sand, in addition it increases the difficulty of pulling a train if a heavy layer of sand is spread upon the rails continuously.

In one particular type of sander, known as the "Graham-White Sander," an additional air connection is made from the engineer's operating valve to the sand trap. This additional air supply pipe is for the purpose of blowing a current of air through the sand delivery pipes through a much larger opening than provided in the sanding nozzles described above. The object being to clear the delivery pipes of wet sand or other obstructions, in case such obstructions exist. It is a well-known fact that when sand becomes wet it packs and will not flow freely. Sometimes moisture accumulates inside the sand pipes near the bottom, and when using the sanders the sand tends to stick to the inside of the pipes at this point. If this condition continues, the sand will gradually pack in the pipe until the pipe is stopped up, when it is necessary to tap the pipe sufficiently to dislodge the wet sand and cause it to fall out of the pipe. If, however, a large volume of air under heavy pressure is admitted to the sand trap, the wet sand can usually be blown clear of the pipe, permitting proper operation of the sander when air is admitted to the sanding nozzles.

The engineer's operating valve for the Graham-White sander is so arranged that when the valve is closed, the handle sets at about 45 degrees angle to the valve body. Moving the handle to its first open position, or at right angles to the valve body, opens the blow-out pipe for blowing out the delivery pipes. Moving the handle around to its second, or sanding position (in which case the handle is parallel or in line with the valve body) shuts off air to the blow-out pipe and admits air to the supply pipe leading to the sanding nozzles.

In using the sanders move the valve to the blow-out position momentarily, or for just a few seconds, then move the handle around to its sanding position. Do not leave the handle in the cleaning or blow-out position except momentarily. The pipes and passages leading from the main reservoir are quite large and if the handle is left in this position too long, the main reservoir pressure will be reduced, which might cause a loss of excess pressure, which would cause the brakes upon the engine or train to apply.

Report all leaks observed in the air pipes leading to the sanders, and also any leaks which will permit moisture to enter the sand box or the sand traps. Usually leaks around the sand box and sand traps will be evidenced by signs of sand or sand dust at such places. When this is observed report promptly, so that repairs can be made to prevent moisture entering the traps or sand box, which might cause the sand to become wet and packed, interfering with the proper operation of the sanding devices.

PNEUMATIC FIRE DOORS

To relieve the fireman of the labor of opening and closing the swinging fire door, automatic fire doors are applied, the doors are operated by compressed air. A small cylinder is provided to operate the door, the piston of such cylinder transmits motion to the fire door by means of a link or lever. In most cases the fire door consists of two parts, and a link or lever connects to each section of the door, which provides for both sections opening in unison.

A foot pedal, located so as to just clear the cab floor, is placed in such position as to be convenient for the fireman to operate with his foot, when standing in his usual position for firing the locomotive. To operate the door press down on the foot pedal, which raises a valve from its seat, admitting air from the main reservoir to the operating cylinder. This moves the piston in the cylinder, causing the door to open. To close the door release the foot pedal, the supply of air from the main reservoir is then cut off from the cylinder and the air in the cylinder is exhausted, allowing the door to close.

Provision is made to hold the door partly or entirely open, by the operation of a hand lever attached to the door, when air pressure is not available.

The door should be closed after each scoop of coal is applied to the firebox.

Oil the various pins connecting the rods and levers once each trip. The cylinder should be oiled through the oil cup, and the pins and levers oiled through oil holes provided for that purpose.

Provision is made by applying an adjustable choke in the exhaust passage leading from the operating cylinder so that the pressure will be exhausted from the cylinder at such a rate as will prevent the doors closing suddenly and striking each other with considerable force. When it is noticed that the doors do operate in this manner report should be made so that proper adjustment of the choke can be made to provide for the doors closing gently.

FLANGE LUBRICATOR

Since the flanges upon the wheels are the only means of maintaining an engine or car in place on the track, or guiding same around curves, it is obvious that they and the rails are both subject to wear when these two surfaces come into contact with each other.

The main frames of a locomotive are not permitted to turn under the boiler in the same manner as is common to the ordinary two, four or six wheel truck, and it therefore requires a greater effort on the part of the flanges on the driving wheels to guide the engine, than is the case with the truck wheels at either end.

A large per cent of the guiding effort is produced by the leading trucks and trailing trucks upon the locomotive, but notwithstanding this, such trucks are free to turn or move from side to side, while any side movement of the driving wheels cannot be transmitted to the main frames, in the same manner as is common to the leading and trailing trucks. The flange wear is therefore greater

than is common to the smaller size wheels used in the ordinary truck.

To reduce the wear of the driving wheel flanges and also the inside edges of the rails, flange oilers are applied. The flange oiler is constructed on the same principle as the lubricator which is used to lubricate the main valves in the steam chests or valve chambers. This flange oiler is located in the cab, on the left side of the boiler head. Suitable pipe connections lead from the flange oiler to the driving wheels that are to have the flanges lubricated. Nozzles are applied at the end of these pipes to direct the oil on the face of the flange. This provides for placing a coating of oil on the flange as the driving wheels revolve.

The flange oiler consists of an oil bowl, which holds about one quart of oil. Above the oil bowl is a condensing coil. Steam is admitted from the boiler into the condensing coil, and at the same time passes around the condensing coil to each side of the lubricator, where it connects to the delivery pipe connection leading to the driving wheels at each side of the locomotive. Above the point where the oil delivery pipe connects to the lubricator, is a sight glass, and just above this point is located a feed valve. The connection to the feed valve leads inside of the lubricator bowl and is piped to the top of the bowl. At the bottom of the condensing coil a valve is located, which permits water from the condensing coil to pass to the bottom of the oil bowl.

As steam enters the condensing coil it has no means of circulating through the lubricator. It consequently condenses into water. This water is passed beneath the oil in the oil bowl, causing the oil to raise on top of the water, where the oil flows into the pipe which conducts the oil to the feed valves. When the feed valves are opened the oil is permitted to flow through the feed valve, where it drops past the sight feed glasses into the current of steam flowing through the oil delivery pipes. The current of steam which is flowing out through the delivery pipes carries the oil with it to the nozzles located close to the flanges, where the oil is blown upon the flange by the current of steam. The nozzles should be located close to the flanges and directed so that the oil will be blown upon the flange and not upon the tread of the wheel.

A steam valve, located in the steam pipe leading from the fountain to the condenser, permits of shutting off steam to the flange oiler. The valve located below the condenser permits of shutting off the flow of water from the condenser to the oil bowl. The feed valves located below the sight feed glasses permits of shutting off oil from the flange oilers to the delivery pipes. A drain valve, located in the bottom of the lubricator provides for draining the water out when it is desired to refill the oil bowl, and a filling plug at the top is provided for refilling the bowl.

The above flange oiler is illustrated in Fig. 42.

LIST OF PARTS—FLANGE OILER

34. Drain valve for oil bowl
35. Steam connection
69. Packing nut for glass
70. Follower ring and washer for glasses
80. Solid glass for sight feed
89. Gaskets for solid glasses
185. Oil bowl
189. Feed valve
191. Condenser valve complete
193. Filler plug
194. Feed tips
197. Flange nozzle
198. Steam pipe choke
201. Choke for oil delivery pipe
292. Steam valve

TO OPERATE FLANGE OILER

To operate—open steam full at boiler. Open steam valve 292 three full turns. Open condenser valve 191 three turns, then regulate feed of oil with feed valves 189.

To Fill oil Bowl—First, close all feed valves (189). Second, close condenser valve 191. Third, close steam valve 292. Fourth, open drain valve plug 34, and then carefully remove filler plug 193. When oil bowl is drained, close drain valve plug 34, and fill the bowl with oil.

Rate of Feed—Oil should be fed at the rate of 12 to 15 drops per minute, or faster, as required, to keep the flanges thoroughly coated. Let the flange be the indicator and regulate feeds accordingly.

When Starting on Run—Open main steam valve at least 15 minutes before setting the oil feeds, and when finishing the run, shut off the oil feeds 189 and condenser valve 191, leaving steam on to clean out the delivery pipes, thus preventing stoppage and freeze-ups. In cold weather be sure and leave steam turned on at all times when engine is not in the roundhouse.

Too Much Steam—If too much steam appears at the flange nozzles, have the steam choke 198 renewed. Do not try and regulate the steam supply with the steam valve 292, as this practice will contribute to stoppages.

To Clean Flange Nozzles 197—Remove cap 63 and run a wire through the opening; then turn on the steam and blow out pipes.

Adjustment of Flange Nozzles—If the lubricant is delivered to the tread of wheel, it indicates improper adjustment of flange nozzle 197. Adjust this nozzle to deliver the lubricant into the throat of the flange without putting any lubricant on the tread of wheel.

Cleaning Feeds and Sight Feed Glasses—First, close condenser valve 191, then open drain valve plug 34, and drain oil bowl. Leave the drain valve open, then open feed valves 189, one at a time, permitting steam to pass back through the feed pocket and feed tips into the oil bowl and out through the drain.

LUBRICATOR

In order to provide for lubricating the main valves in the steam chests or valve chambers continuously, while the engine is working steam, a main lubricator is located in the cab. Fig. 43 illustrates the five-feed lubricator in common use. It will be found that some engines are equipped with a three-feed lubricator, the operation of which, however, is identical with that of the five feed.

List of parts

9. Steam connection
23. Filler plug
31. Feed valve for pump
33. Drain valve
34. Drain valve plug for oil bowl
62. Pressure valve
65. Auxiliary oil cup
66. Auxiliary oil cup filler plug
69. Packing nut for glass
70. Follower ring and washer for glass
73. Water valve
78. Auxiliary oil cup feed valve (run closed when not in use.)
80. Solid glasses, sight feed or index.
88. Auxiliary oil cup drain valve
89. Gaskets for solid glasses.
175. Low pressure feed valve
176. High pressure feed valve

The principle of operation of the lubricator is as follows:

The central portion or body 171, of the lubricator is an oil bowl with a capacity of three or five pints. Above the oil bowl is located another small bowl or condensing chamber 71. A steam pipe connection connected at 9 leads to a connection at the top of the boiler. Steam is therefore admitted to the condensing chamber through connection 9, past check valve 4 and through pipe 91 to the condensing chamber 71. Since there is no circulation of steam from the condenser 71 through the lubricator, any steam passing into the condenser is condensed into water. When valve 73 is open, water from the condenser is permitted to pass through pipe 104 to the bottom of the oil bowl or reservoir 171. Any oil in the oil bowl is therefore raised on top of the water to the top of the oil bowl and flows down pipe 177 to feed tips 81. It will be noted there is a feed tip 81 located on top of the oil bowl, oil is therefore caused to flow to all these feed tips 81. At the same time steam passes through pipes 173 and 174 to the top of the sight feed glass chamber at valve 62, where it passes out through the connection 36, then through choke valve 56 and to the steam chest or valve chamber. When valves 62 are open steam is also admitted to the space above the feed tips 81 between the sight feed glasses. As there is no circulation of steam in the chamber above the feed tips, this space also fills with water. Solid sight feed glasses are provided through which the feed tips 81 may be plainly seen.

With the lubricator filled with oil and valves 73 and 62 opened, and the main valve open at steam pipe connection 9 at the fountain, the lubricator is ready to start.

Since the condenser 71 is full of water, and this water is passed through pipe 104 under the oil in the oil bowl, the oil has been raised up on top of the water to the feed tip 81. When valves 175 and 176 are open the oil is forced through the feed tip 81, where it rises through the water in the form of drops of oil, which can be plainly seen by looking through the sight glasses 80. The oil rises through the water in the sight glass chambers where it passes through the oil pipe connections 35 and choke 56 to the steam chests.

As the oil is fed out of the oil bowl 171, water passes down from the condenser 71 which continues to raise the oil in the oil bowl. When valve 31 is open oil is fed through feed tip 81, through choke 36 and pipe connection leading to the air pump.

The choke 56 is connected in the oil delivery pipes close to the steam chest or valve chamber. The opening through this choke valve being very small permits a light flow of steam through the oil pipe, sufficient however, to properly deliver the oil to the steam chest. At the same time it maintains the same pressure in the oil delivery pipe between the choke valve and the lubricator as is carried on the lubricator. In this way the pressure of steam on the water in the sight glass chambers and in the condenser is balanced. The condenser being above the oil bowl provides for the weight of the water in the condenser raising the oil in the oil bowl. The light flow of steam through the oil pipe provides for sufficient circulation to assist in carrying the oil from the lubricator to the valve chambers and cylinders.

TO OPERATE THE LUBRICATOR

Open steam valve full at boiler. Open valves 62 one turn. Open water valve 73 three turns. Note the feed glasses to see if filled with condensation. After the glasses are filled regulate feeds with valves 31, 175 and 176.

To blow out glasses: Close feed valve 31 or 175 or 176 and pressure valve 62; open valve 33 to exhaust pressure, after which regulate flow of steam through glass with valve 62.

To fill glasses with water: Close valve 33 and open valve 62 one turn.

To operate auxiliary oil cup 65, close pressure valve 62. See that valve 78 is closed. Open auxiliary drain valve 88 to free cup of water. Open auxiliary filler plug 66 and fill. After cup is filled close cup tight and open feed valve 78 wide. One filling of auxiliary oil cup will feed one hour. This auxiliary cup can be operated with steam on lubricator and engine throttle open.

To remove gaskets or glasses with steam pressure on lubricator: Close valve 62; open valve 33 to drain, then remove packing nut 69, follower washer 70, and gasket 89 with small packing hook. After gasket is removed glass will come out.

To renew glasses: Put washer 70 in first to make a seat between metal and glass; then place gasket on glass, insert large end of

glass first; put another follower washer 70 in place on top of gasket and screw packing nut until the necessary resistance is felt.

Regulate feeds to suit requirements.

The draft from an open cab window, if it strikes directly on the sight feed glasses and is permitted to chill the glasses, considerably, may affect the operation of the lubricator; that is, there will be a difference in the rate of feeding when the water is cold over that obtaining when the water is warm in the sight glass chambers. Ordinarily the feeding of the lubricator is affected but very little in this manner, unless a strong current of cold air is allowed to blow on the lubricator continuously.

If there is dirt or other foreign matter in the feed tip 81, or in the choke 57, or if the choke 57 is worn, the feeding of the lubricator may be irregular. A reduced steam pipe, or a steam pipe too small, or an obstruction in the steam or oil delivery pipes will have the same effect. If the chokes are worn or there is a lack of steam pressure on the lubricator, the lubricator will feed faster when the throttle is closed than when open.

With lubricators having solid sight glasses, as described above, no bad results will follow filling the lubricator full of cold oil; because an expansion chamber has been provided to allow the oil to expand when it becomes heated. With the older type lubricators, having tubular glasses, the oil bowl should not be filled to overflowing with cold oil.

If the sight feeds get stopped up blow out the glasses. To blow out the chokes 57, first shut off steam to the lubricator in the pipe connection 9, drain the sight feed chambers by opening valves 33, open the throttle and let steam blow back from the steam chest or valve chambers. If this fails disconnect the pipes and run a wire through the chokes. When necessary to resort to this practice proper report should be made at terminal so that chokes may be put in good order.

When shutting off the lubricator, such as standing in sidings, or other places, close the oil feeds 175 and 176.

The amount of oil fed to the valve chambers should be sufficient to properly lubricate the valves. The amount to be fed depends upon the conditions at all times. No more oil than necessary should be fed, and where oil pipe connections are used in the locomotive cylinders, two drops of oil should be fed to the cylinders for each three fed to the valve chambers.

To fill the oil bowl close the valve in the steam supply pipe 9 at the fountain, close valve 73 and valves 175 and 176, and 31. Open drain valve 34 and allow all the water in the oil bowl to drain out. As soon as oil shows at drain valve 34 this valve should be closed. Loosen filling plug 23, if the lubricator is hot care must be taken in removing plug 23 as the oil in the bowl may boil out of the opening. After the oil bowl is filled, see that plug 23 is screwed in firmly. In case the lubricator does not operate, the valves may be lubricated through auxiliary oil cups 65.

When five-feed lubricators are used on compound engines, the feeds 175 lead to the low pressure valve chambers or steam chests, and the feeds 176 lead to the high pressure valve chambers or steam chests. On simple engines, having oil pipe connections leading into the cylinders, the feeds 175 deliver oil to the cylinders and the feeds 176 deliver oil to the steam chests or valve chambers.

INJECTORS

Fig. 44 illustrates the construction of the lifting injector.

List of Parts

1. Body (back part)
2. Body (front part)
3. Delivery end connection
4. Steam valve hub
5. Steam valve nut
6. Steam valve gland
7. Overflow nozzle
8. Lever handle—complete
9. Steam valve crosshead
10. Crosshead lock nut
11. Steam valve steam
12. Swivel nut
13. Steam valve
14. Steam valve washer
15. Primer
16. Steam tube
17. Lifting tube
18. Condensing tube
19. Delivery tube
20. Line check valve
21. Stop ring
22. Overflow hub
23. Overflow valve stem

23A. Handle for overflow valve

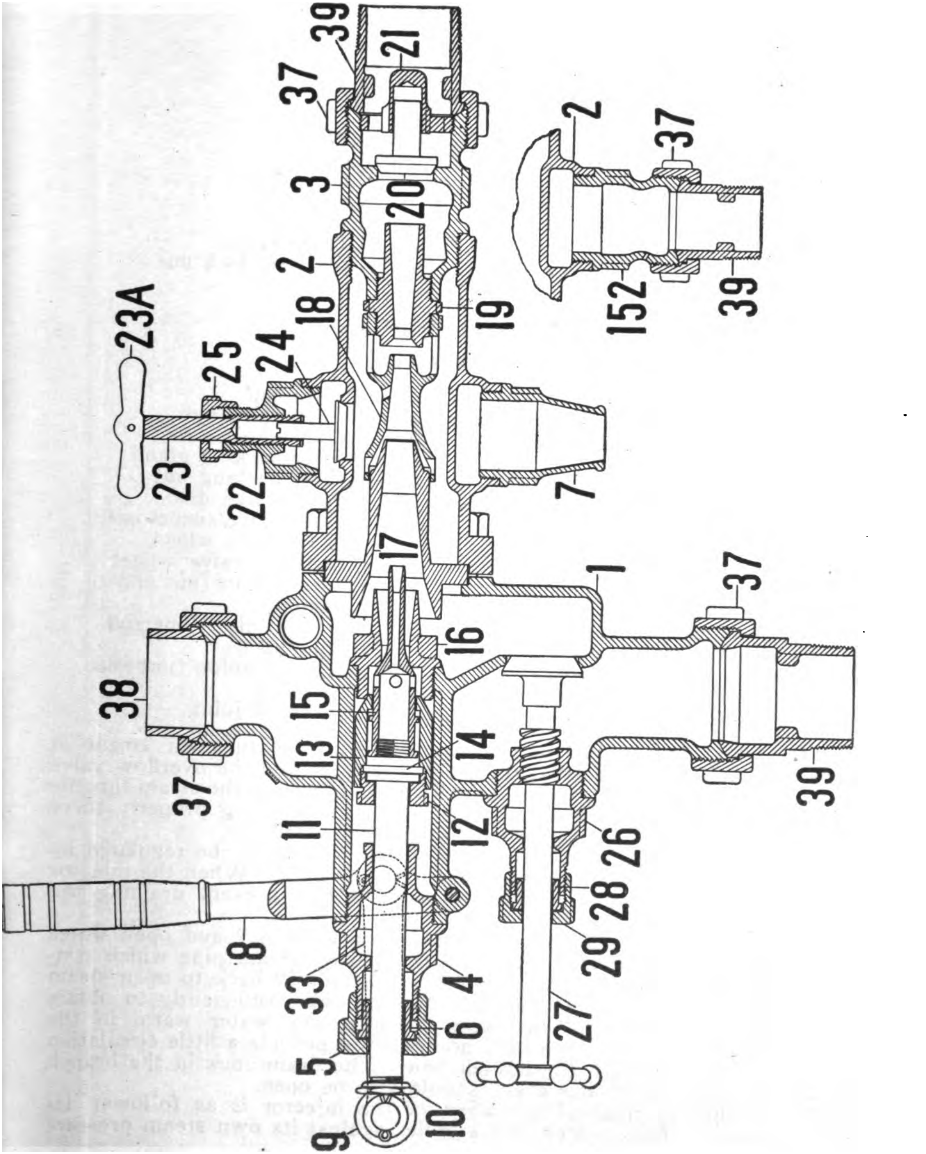
24. Overflow valve
25. Overflow packing nut
26. Water valve hub
27. Water valve spindle
28. Water valve packing gland
29. Water valve nut
33. Lever links
37. Coupling nuts
38. Couplings, copper
39. Couplings, iron
152. Closed overflow connection

The method of operation is as follows:

First turn on steam at fountain valve. To start the injector see that valve 23A, and valve 27 are open, then pulling back slightly on handle 8, until the resistance of the priming valve is felt. When water appears at the overflow 7 pull handle 8 back as far as it will go. Regulate for quantity of water desired by opening or closing water or feed valve 27.

To use as a heater close overflow valve 23A, open valve 27 and pull lever 8 back until the resistance of the priming valve is felt. Sometimes the steam pressure inside the injector forces handle 8 clear back, in which event close down on the fountain valve in the main steam pipe, which connects to the injector at 38, until the desired amount of steam is passing through the injector to keep the water in the feed pipe and tank hose warm, and also provide a little circulation of steam through the injector branch pipe. If there is danger of the branch pipe freezing up, the drain cock in the branch pipe located near the boiler check valve should be opened.

The overflow valve 23A must not be closed except when the injector is to be used as a heater. It is important that the tank valve be kept wide open, that all pipe joints and joints at the injector be kept tight, the tank hose strainer should be kept clean, and the packing in the stuffing boxes 6 and 28 should be kept in good condition.


39
21
37
3
20
2
19
18
24
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23A
23
22
7
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13
14
37
11
12
26
39
28
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33
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27
6
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10
9
2
37
152
39

FIG. 44.

Fig. 45 illustrates the non-lifting injector.

List of Parts

Throttle Valve

61.	Body	69.	Lever pin
62.	Hub	70.	Lever
63.	Packing gland	71.	Lever link
64.	Packing nut	72.	Link pin
65.	Valve	37.	Union nut
66.	Swivel nut	38.	Union nipple
67.	Spindle	60.	Crosshead lock nut
68.	Crosshead		

List of Parts

Injector

260.	Body	307.	Barrel cap
301.	Lifting steam jet	267.	Water valve hub
302.	Forcing steam jet	268.	Water valve stem
303.	Lifting tube	269.	Water packing gland
304.	Rear combining tube	270.	Water packing nut
305.	Forward combining tube	316.	Water valve disc
306.	Delivery tube	317.	Water valve swivel nut
261.	Overflow body	328.	Water valve wheel
262.	Overflow connection nipple	329.	Overflow valve wheel
263.	Overflow connection nut	337.	Steam union (nut and nipple)
264.	Overflow cap		
265.	Overflow hub	338.	Supply union (nut and nipple)
266.	Overflow stem		
309.	Overflow check	339.	Delivery union (nut and nipple)
312.	Overflow packing nut		
313.	Overflow packing gland	271.	Universal joint

To operate the non-lifting injector, first turn on steam at fountain valve, see that the water valve 328 and the overflow valve 329 are open. Pull back gradually on handle 70 of the steam throttle valve until wide open. If the injector is working properly there should be no water spilling at the overflow 338.

The desired supply of water to the boiler may be regulated by either opening or closing water feed valve 328. When the injector is shut off close the overflow valve 329 to prevent draining the water from the tender.

To use as a heater, close overflow valve 329 and open water valve 328, shut off fountain valve in main steam pipe which connects to injector at 337; then move handle 70 back to open steam valve 67 wide, then open the fountain valve sufficiently to obtain the desired amount of steam to keep the water warm in the injector, feed pipe and tank hose, also to provide a little circulation of steam through the branch pipe. The drain cock in the branch pipe, near the boiler check should also be open.

The principal of operation of the injector is as follows: Its power to force water into a boiler against its own steam pressure

is due to the difference between kinetic or moving energy, and static or standing energy. Steam at the ordinary boiler pressure travels at a very high velocity and when placed in contact with a stream of water it is condensed into water, at the same time imparting its velocity to the water which condenses it. This, of course, gives a high momentum to the body of water with which the steam comes into contact. The momentum imparted to the water in an injector is enabled to overcome a pressure greater than the original pressure of the steam.

The velocity of the steam passing through the tubes in an injector is imparted to the water entering the branch pipe, which gives the water in the branch pipe sufficient energy to open the check valve and enter the boiler against its own pressure.

Injectors of the lifting type must, of course, create a sufficient vacuum in the water feed pipe to raise the water from the level in the tank to the height of the injector. In other words, the priming valve drives the air out of the injector, which causes a vacuum in the feed pipe. This allows the atmospheric pressure on the water in the tender to force the water through the feed pipe into the injector, where is condenses the water passing from the priming valve and flows out through the overflow pipe.

Injectors of the non-lifting type are located below the level of the water in the tank so that the water will flow to it by gravity. If there is a bad leak which admits air into the water feed pipe the lifting injector will not work, it will not prime because the leak destroys the vacuum necessary to raise the water in the feed pipe. However, a non-lifting injector may work under these conditions, particularly if the water escaping from the pipe prevents any air being drawn into it as is the case with the lifting injector.

Other causes for the injector not working are an insufficient supply of water or the tank valve being closed or partly closed. The strainers may be stopped up or the tank hose kinked. Injector tubes out of line or badly limed up, the delivery tubes may be cut out, there may be too much water in the steam coming from the boiler, or the water in the tender may be too hot. Trouble may be experienced in getting the injector to prime properly if there is an insufficient water supply in the tank, or if the tank valve is closed or partly closed. There may be an obstruction in the tank hose or strainer may be stopped up. With the lifting type injectors, the trouble may be caused by a leak in the water feed pipe. Also if the boiler checks are leaking badly or stuck up, or the injector throttle leaks bad. The boiler check may be stuck shut or there may be an obstruction in the branch pipe. The line check valve may be stuck shut or broken.

If, when the injector is shut off or not working, steam or water shows at the overflow pipe, this may be either from boiler check leaking or the injector throttle leaking. Closing the main steam valve on the boiler will stop the flow of steam or water, if it comes from the injector throttle. In case the primer valve is leaking, it will not prevent the primer or injector working, but may waste considerable water from the overflow.

Sometimes all the steam passing through the injector is not condensed by the water. Under these conditions the injector may

work but spill hot steam and water at the overflow. If only a very little steam is condensed, the injector will not work. If the injector spills cold water at the overflow, there is too much water for the amount of steam passing through the injector. If some steam and very hot water escapes at the overflow while the injector is working, there is too much steam for the amount of water being supplied. In the former case the amount of water passing through the water feed pipe should be reduced and in the latter case the amount of water passing through the water feed pipe should be increased, or the steam pressure reduced. It may be that in the former case there is not sufficient steam pressure on the boiler, or the steam fountain valve not opened wide enough, and in the latter case an obstruction somewhere in the water supply leading to the injector.

A leaky injector throttle heats the water in the top of injector water pipe. If this hot water can be blown back into the tank the injector will prime.

If the injector primes properly, but breaks when steam is turned on wide, examine main steam fountain valve and valve on injector steam pipe, to see if full open. Next examine feed line for obstructions. If injector continues to fail, examine combining and delivery tubes for defects or obstructions.

If the injector will not prime examine from overflow back, including the steam supply pipe connections, strainers, hose, hose couplings, tank valve or syphon pipe.

In case the boiler check valve is stuck open, tap the check case lightly on the top or bottom. If using a hammer or other metal piece, do not strike the check valve cage heavily on its side, as this tends to spring the check case so that the check valve will not seat tightly.

It is sometimes possible to get the injector to prime and start working by opening the drain cock in the branch pipe or ash pan flooder or both, if the branch pipe or check is equipped with a connection for filling the boiler, this may be opened to reduce the pressure at the injector to assist in getting the injector to prime. In some cases the check valve is equipped with a valve stem for closing the check valve from the branch pipe, this valve may be closed to stop the flow of water and steam from the boiler to the branch pipe, the injector may then be primed and started to work carefully, open the valve at the check after priming, and if the injector continues to prime properly it may be started to work in the usual manner. If the primer breaks when the valve is opened close it again and prime the injector, then open the injector throttle carefully to get the injector to spill a full stream of water at the overflow with the injector throttle open, then open the valve at the boiler check. If the water is not forced into the boiler, gradually close the water feed valve until the injector does start the water through the check valve into the boiler. The water feed valve may then be adjusted to the desired position. After getting the injector to work, all openings made in the branch pipe should be closed. If it is impossible to get the check valve seated, or the injector to work, close the water feed valve and the overflow valve, then close the injector steam pipe fountain valve to separate the injector from other connections at the fountain.

Where the water feed pipes leading to the tender are not equipped with tank valves to shut off the water supply, a small syphon cock is provided in the connection on the tank head; opening this admits air to the water feed pipe which prevents syphoning the water out in case the tank hose was disconnected.

To operate the injector as a heater, close the overflow valve, open the drain cock in the front end of the branch pipe and close the valve in the injector steam pipe at the fountain. Open the injector throttle, then slightly open the fountain valve to the injector to admit sufficient steam to provide for circulation through the branch pipe and the tank hose to prevent freezing. At the same time care should be exercized not to admit sufficient steam so that too much pressure will be built up which might cause the tank hose to burst or blow off. Do this in freezing weather on injectors which are not being operated regularly, to prevent freezing up of the branch pipe, feed water pipe and tank hose.

SAFETY VALVES

The safety valve used upon locomotive boilers to regulate the steam pressure therein is illustrated in Fig. 46. Where two safety valves are applied, one of them is adjusted to blow at the standard pressure for the boiler, the second safety valve is adjusted to blow at two pounds above this pressure. Where three safety valves are employed, the first one is adjusted to blow at the standard pressure for the boiler, the second one adjusted to blow at two pounds above this pressure, and the third one adjusted to blow five pounds above the standard pressure.

The safety valves are properly adjusted when applied to the locomotive, and their adjustment should not be disturbed. After the safety valves are properly adjusted they are locked with a seal, which must be broken which will provide for removing a cap to permit of turning the adjusting screw.

In case a safety valve spring was broken, so that the valve blowed continuously when the steam pressure reduced below that standard to the boiler, the adjusting screw 4 may be screwed down until the stem is forced down solid on valve 11, thus holding it tightly to its seat.

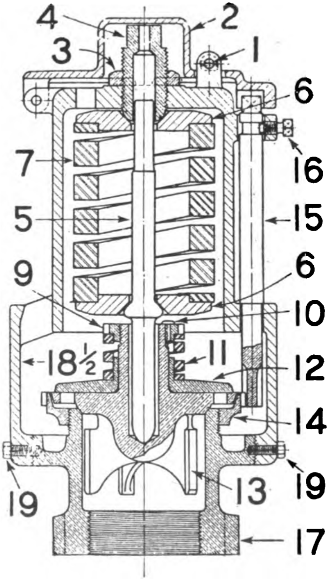

Fig. 46.

ELECTRIC HEADLIGHT

The electric headlight equipment on a locomotive consists of a turbine motor connected to a dynamo, the dynamo and motor being constructed as a single unit and both being rigidly attached to a single shaft, the motor being operated by steam pressure taken from the boiler.

Fig. 47 shows the "E" type motor and dynamo complete, and Fig. 48 shows the "C" type.

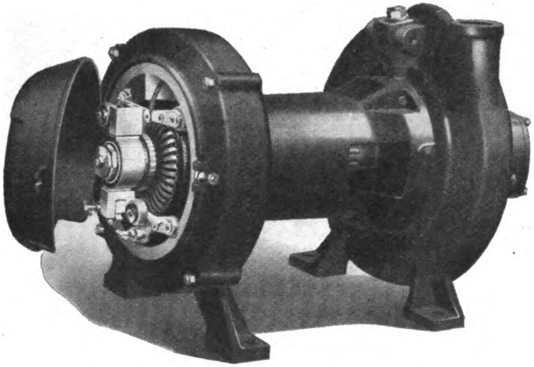

FIG. 47.

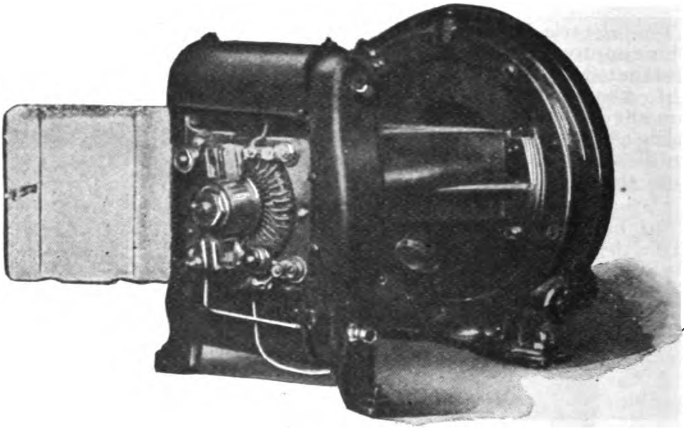

Fig. 48.

Fig. 49 shows the reflector and lamp stand complete. This reflector and lamp stand is suitable for the usual standard headlight casing.

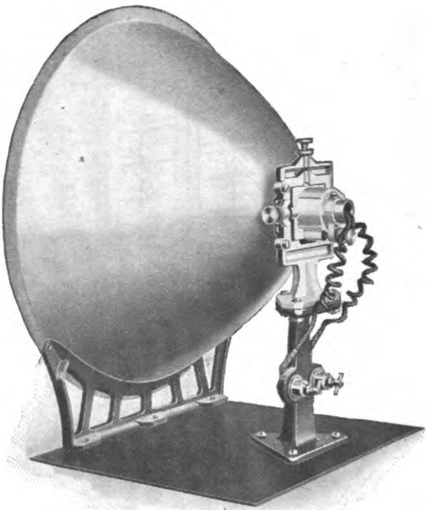

Fig. 49.

Fig. 50 shows the adjustable lamp stand which sets directly behind the reflector and to which the reflector is attached.

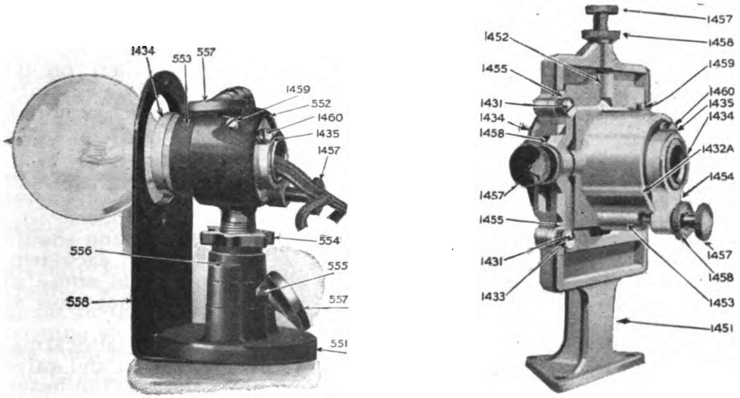

Fig. 50.

A system of wires connect the dynamo to the headlight and the cab lamps. A switch, conveniently located in the cab, provides for turning off the headlight as desired.

The headlight should be adjusted so that the front edge of the reflector will be parallel with the front edge of the headlight cage or case. To focus the lamp, the locomotive should be on straight track and adjustment should be made to obtain a parallel beam of light straight down the center of the track. All of the adjusting screws should then be tightened firmly. For road work the shaft or beam of light should extend at least 800 feet ahead of the engine, and for yard work at least 300 feet.

A newly applied headlight should always be focused before going into service. This can best be done at night or in a dark room. To focus the light, throw the light from the reflector upon a wall or the end of a car from fifty to seventy-five feet away, and manipulate the lamp (up and down or side-ways) by using the focal adjusting thumb screws of the focusing device until a perfect light circle is obtained. The light is in focus when the light circle is

reduced to its smallest possible size by movement of the lamp forward or backward. After obtaining a good focus tighten the lock nuts on the focal adjusting screws, place the reflector in its case and close the door. The light beam should be central on straight level track and should be directed so as to define persons from 800 to 1,000 feet away. If the beam of light is not central it may be necessary to swing the headlight case to the right or left on its bracket. To raise or lower the beam of light it may be necessary to shim up the front or back of the headlight case as required. A black spot or shadow on the track within the light rays indicates that the lamp is not in focus in its reflector.

When renewing globes in the headlight it may be necessary to re-focus the lamp, as the filament or wire in each globe is not located the same in exact relation to the center of the globe.

To insure a good and unfailing light a careful inspection should be made of the lighting equipment before departing on each trip. All screws and connections should be known to be tight and also that there is oil in both bearings, and that steam does not blow at the stuffing box gland.

During winter months dynamo oil should be used for lubricating, and during the summer months a mixture of dynamo oil and valve oil should be used. Do not use valve oil alone, such oil is too heavy to be carried up to the shaft by the oil ring, particularly in cold weather. The turbine bearing should be oiled each trip. Oil for the dynamo bearing is introduced through an oil cup located on the side of the main turbine casing at the back of the dynamo. When a hinged oil cup cover is used do not fill the cup completely full. When a screwed oil cup cover is used the cup may be completely filled. To oil the turbine motor an oil cup is located on the turbine cover.

In starting the motor and dynamo turn the steam on slowly at the fountain valve in the cab, in order to permit the water from condensation to pass through the drain pipe. The throttle valve should be opened wide enough when in regular service, so that the lights will burn clear and bright. The engineman should take into consideration the steam pressure when adjusting the throttle valve to the turbine. If the steam pressure is at or near full boiler pressure, the throttle may be adjusted for the trip. If, however, the steam pressure is considerably below full pressure, the throttle should again be adjusted after the steam pressure is close to the popping point.

The most vital part of the dynamo, which is, of course, that part of the equipment which generates the electric current, is the commutator. The commutator must be kept clean and free from dirt. The mica strips between the sections of the commutator must be kept below the surface of the commutator face. In cleaning the commutator remove both brushes and rub lengthwise of the bars with a piece of moist clean waste. This removes the carbon dust from between the segments or bars as well as all dirt from the surface of the commutator. Replace brushes and generator is ready to start.

If it is necessary to clean the commutator by polishing it, it should be smoothed by means of a strip of No. 0 sandpaper held in contact with the commutator while turbine is running. Hold

sandpaper by its ends and do not press against it with the fingers, as this will increase the size of any spots that may be on the commutator. The mica insulation between the commutator bars should be maintained 1-64 inch below the surface.

The brushes which bear on the commutator should have a bearing of the same contour as the commutator. The brushes may be fitted by cutting a strip of No. 0 sandpaper the width of the commutator surface, then with the dynamo running press the strips of sandpaper under the brushes, with the back of the sandpaper next to the commutator surface. Allow the brushes to drop in place, then pull the sandpaper from left to right until the brushes have ben fitted to a true smooth bearing, then trim about 1/8 inch off of the front end of the brushes. Never attempt to fit a brush with a file.

When trouble suddenly occurs, if the light has been burning steadily and nicely and then suddenly begins to flash badly, the trouble will usually be found at one of the binding posts, on account of the binding post screws becoming loose. If the light is burning satisfactorily and suddenly goes out it may be that either the lamp had burned out, one of the lead wires has broken between the dynamo and lamp or one of the wires had botten loose at its binding post and fallen out. If the light does go out between stations and an investigation cannot be made within a few minutes thereafter to determine the cause, steam should be shut off from the turbine motor until such time as the cause of failure can be determined. Otherwise if the failure is due to a short circuit damage might be done to the coils or armature in the dynamo by overheating.

When there is a short circuit in any of the connections, which is brought about by the insulation on the wires becoming worn off until two wires can come together either directly or through the medium of some metallic substance, the turbine motor will labor heavily and run slow with a large volume of steam blowing at the exhaust. There will be no light shown at the headlight or cab lamps, or the cab lamps may only show a dull red light.

When the circuit is broken either by a broken or disconnected wire, or a burned out lamp, the turbine motor will run noiselessly and very fast with little steam blowing at the exhaust. The headlight or cab lamps will not burn.

In the case of a short circuit due to the insulation being worn off the wire or the wire touching some metallic substance, if the exposed wire can be located, wrap it with a piece of waste or cloth to act as insulation.

In case of a broken wire if the broken section can be gotten at, temporary repairs might be made by stripping off the insulation far enough back at the end of each section so that the two pieces of wire might be firmly bound together. See that the ends of the wire are scraped thoroughly clean before twisting them together, wrap the joint in the wire with a piece of cloth if there is liability of them touching anything.

Sparking of the commutator at the contact of the brushes may be caused by the brush being poorly surfaced, the brush may be too short, the commutator surface may be rough or the commutator

may not be running true, the mica between the commutator bars may need dressing down.

If the governor valves should become stuck shut or the governor springs are too weak, the light may go out or burn dim if the steam drops back 15 to 20 pounds or more, in which case the action of the turbine motor should be reported on arrival at terminal.

If the cab lights burn up bright when the headlight is cut out, throttle the steam to the turbine motor and report same on work book on arrival at terminal.

The commutator brushes stick up at times in which case the dynamo will not generate current. Poor contacts at switch points and also commutator brushes will keep the light from burning.

The speed of the dynamo should be regulated by the governor so that the voltage will not be over 32 volts at any time. Any voltage over 32 shortens the life of lamp hours and burns them out. Governor valves stick open or shut at times when strainers are stopped up. A little engine oil applied at times through the steam pipe will avoid most of this trouble.

The wiring system for road locomotives is made up in two sections, one section comprising the lighting system for the headlight and dimmer, the other section comprising the balance of the lights on the locomotive. A double throw switch is for the purpose of operating the headlight and dimmer. The cab lamps are operated constantly. The classification lamps are operated by a single throw switch on the left side of the cab. A separate fuse is used for each lighting section. On road locomotives having a headlight at the rear an additional section is applied, controlled by a double throw switch.

In case an individual lamp fails to burn and all other lights burn properly, examine to see if the light has burned out and needs renewing. If none of the lights on a particular section will burn, examine to see if the fuse in that section has burned out. If a fuse has burned out and a new fuse is applied which burns out when the current is turned out, it is evident that some defect exists in the wiring system which causes the fuse to be burned or blown out. To determine if the defect is in the wiring system, or either one of the lights, remove the lights from their sockets in that section, turn on the current and see if the fuse holds, if so, start applying the lights in their sockets until the one is found which causes the fuse to burn out, and either replace or leave the light out of its socket. Sometimes the light becomes loose in its socket so that it does not make a proper contact, in which case screwing the light firmly in place overcomes the trouble.

The headlight or other lights about the engine which are operated by the turbine generator should not be used unnecessarily, and should not be burned during the day time unless absolutely necessary. It requires forty to fifty pounds of water per hour to operate the turbine when only the cab lights are burning, therefore unnecessary use of the lights is simply a waste of coal and water. The turbine motor should be shut off when it is not necessary to use lights.

RAND McNALLY & CO.
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